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WE AGREE.

Professor Alan Robson
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University of Western Australia

Neil Theobald
General Manager,
Gas Marketing & Commercialization
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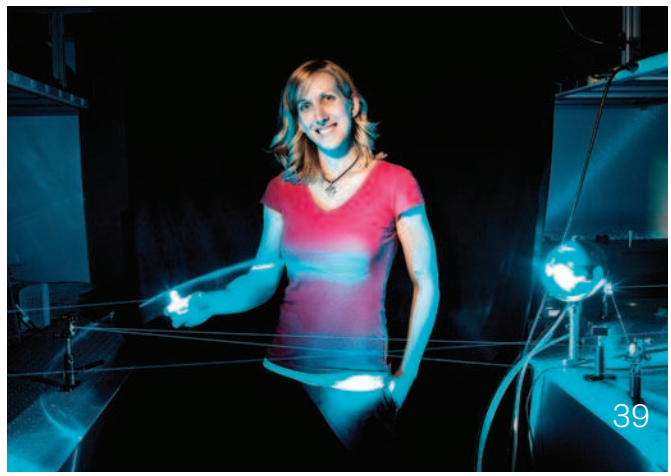

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How Tunisian and Egyptian hackers and soccer fans created the Arab Spring.

By JOHN POLLOCK

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By DAVID EWING DUNCAN

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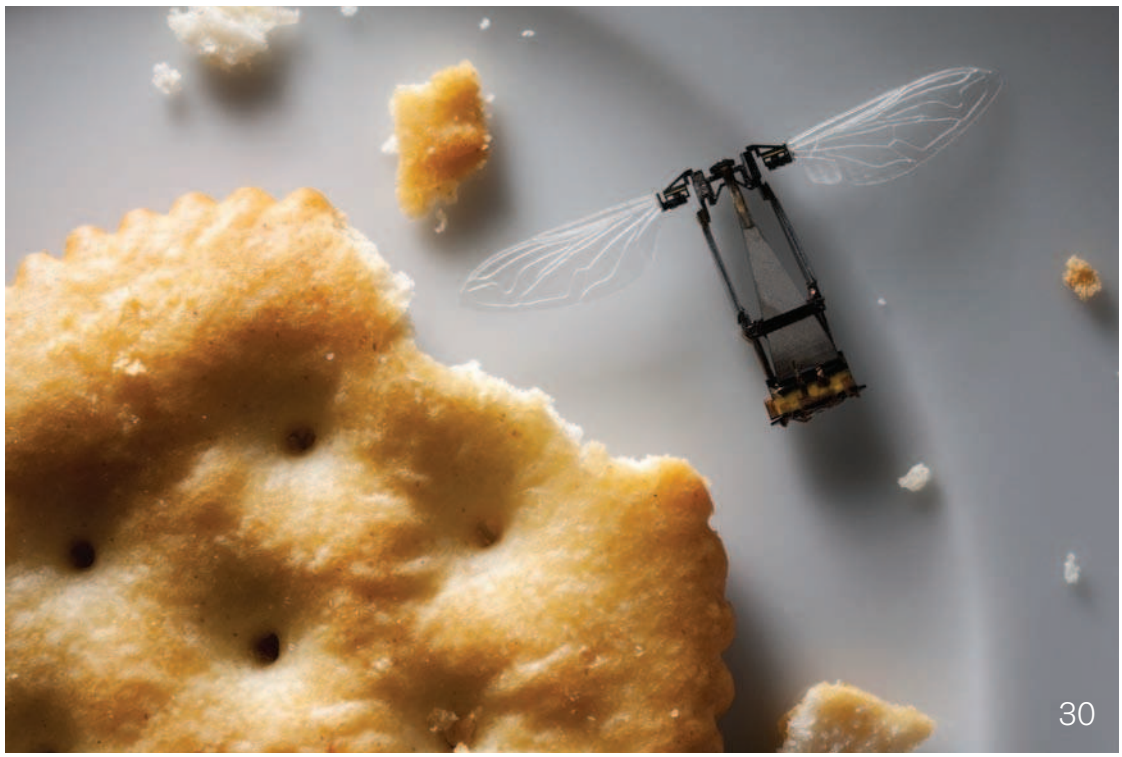

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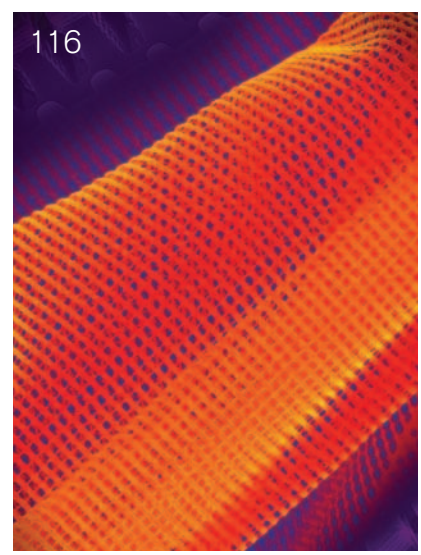

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Letters and Comments

TRACKING PERSONAL HEALTH

Emily Singer's article "The Measured Life" (July/August 2011) not only highlights the potential for self-tracking to improve one's personal health but expands our thinking about the possibilities for personal health data. As a medical doctor and director of the Center for Connected Health, I believe that taken in aggregate, individual patient data can lead to important observations and perhaps even significant findings on a broad range of issues—from lifestyle triggers to treatment outcomes.

July/August 2011

With the ever-increasing availability of consumer technologies to help us track health indicators, daily activity, and even our emotional status, the opportunities for data collection and sharing abound. We certainly have a way to go before we see this kind of self-generated data integrated into mainstream health-care practices. However, we are seeing more and more providers acknowledging the value of patient data generated outside a medical setting.

Joseph C. Kvedar
Boston

A HOME FOR CRIME

In "The Perfect Scam" (July/August 2011), David Talbot perfectly illustrates the dangers of today's digital world. Designed to be used by a handful of people in a friendly way, the Internet has grown bigger than anything its creators envisioned, and cybercrime has found a nice place to nest. As a director at Kaspersky Lab, I think that humans remain the weakest link in the security chain despite advances in computer hardware, new operating systems, and "the cloud." Maybe the time has finally come to design a safer Internet, where people can shop or bank online without having to worry about scams and malware.

Costin Raiu
Bucharest, Romania

FDA AND STEM CELLS

"Stem-Cell Gamble" (July/August 2011) was well balanced and very informative. It will be interesting to watch the FDA's role in either moving forward or stalling early human studies of embryonic-stem-cell research. The stakes are high, with big risks and big benefits. Yet it is important to remember that all forms of medicine have serious risks, and that drug safety has never been guaranteed by the FDA.

Julie Flygare
Arlington, Virginia

SHOULD WE WAIT?

Your editorial ("The Problem with Waiting for Catastrophes," July/August 2011) makes a very important point: it's unfortunate that "many economists consider it respectable to wait until a catastrophe strikes." Waiting for direct evidence that nuclear deterrence can fail is even more unacceptable than waiting for further proof of global warming (a situation where I agree that the principle applies). In fact, that is the primary reason why I lead a project to provoke a reassessment of our nuclear strategy.

Martin Hellman
Stanford, California

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A great piece, but I would counter your argument that waiting for a catastrophe assumes infinite adaptability. Prevention assumes you have a near-perfect knowledge of a complex universe, but in reality there is no clear way to prevent the unknown. Waiting for a catastrophe to happen is like allowing a hidden enemy to reveal himself. You will learn more about the catastrophe and can attack efficiently and with a greater chance of success in the future. We simply don't have the resources to prevent all catastrophes and still allow for innovation and calculated risk-taking. Life is so complex that "doing nothing" and waiting for catastrophe can be a worthwhile option.

J. Foster Davis
Little Rock, Arkansas

OTHER OPTIONS FOR ENERGY

In "Avoiding the 'C' Words" (July/August 2011), Kevin Bullis fails to recognize that top-down policies imposed on markets can yield wasteful programs, as exemplified by ethanol from corn. He shows minuscule faith in the potential for a competitive free-market system to solve our technological challenges while placing trust in draconian dictates imposed by the government. This message runs counter to overwhelming evidence that innovation is the by-product of innumerable scientists, engineers, and entrepreneurs working independently and competitively, nurtured at times by infusions of funding from the government.

Albert Mehrabian
Monterey, California

Energy editor Kevin Bullis responds: The review argues that the government should set clear goals, precisely to avoid problems such as the ones we've seen with ethanol. But if dislodging entrenched energy sources is the goal, that will require more than government R&D funding—it will also require policies that help increase demand for new technologies.

notebooks

HEALTH

Open Up

Paul Wicks says sharing information about your health can advance medical science and improve society.

After my wife and I moved from the U.K. to Boston in 2008, Facebook allowed us to keep in touch with friends back home. Yet we read only a stream of good news. We heard about weddings, birthdays, and nights out, not cancer scares, depression, or the baby not brought to term.

This selective, rose-tinted sharing is common on social networks—except for the one I work on, PatientsLikeMe. There, people with conditions from bipolar disorder to HIV anonymously or publicly share intimate details of symptoms, treatments, and health outcomes with thousands of people they've never met. We have published studies showing that this sharing helps our users become better at managing health problems. We have also shed new light on the effectiveness of rarely studied treatments, such as generic drugs and off-label indications.

These people have proved that there are real benefits to sharing the bad news. I think even more good could be done if everyone, not just those with serious conditions, were to share more health information.

Admittedly, this would take some persuasion. One practical problem is creating a context for such sharing, whether inside ordinary social networks or in dedicated spaces such as PatientsLikeMe. But there's also a more fundamental issue: the deep-seated belief that talking about illness diminishes us in the eyes of others.

We recently conducted a survey asking more than 4,000 PatientsLikeMe users which parts of their social circles they had informed of their diagnosis. Patients with diseases that are visibly obvious, like ALS or Parkinson's disease, had spread the bad news most widely, to family, friends, and neighbors. However, people with conditions whose symptoms are more hidden—such as mental illness, HIV, or epilepsy—were much less likely to reveal their diagnosis. Real-life neighbors and connections on social networks were rarely informed.

The roots of our taboos about health are complex, but humans seem to have a "default privacy setting" that conceals illness from others when possible; it's overridden only when our defenses crumble and the state of our health is plain for all to see. Society can erect similar barriers. Author and oncologist Siddhartha Mukherjee tells us that Fanny Rosenow, a breast cancer activist in the 1950s, was unable to advertise her support group in the *New York Times* because the words "breast" and "cancer" were both taboo. We have made huge strides in medical openness since, but we still have far to go. We should allow and encourage people to be more open with the bad news about their health. Not only will we advance medicine, but our society will become less likely to harm or discriminate against people with health problems.

PAUL WICKS IS ONE OF THIS YEAR'S TR35 (SEE P. 40) AND A RESEARCHER AT PATIENTSLIKEME, A SOCIAL NETWORK FOR SHARING INFORMATION ABOUT LIFE-CHANGING ILLNESS.

ENERGY

Thinking Big

Dramatic changes can come from emerging technology companies partnered with large industry players, says Joel Moxley.

The world needs new energy resources—not only to offset the decline of our existing reserves but to support the rapid growth of emerging economies like those of China, India, Brazil, and Russia. The International Energy Agency estimates that resources yet to be developed or discovered could be needed to account for 50 percent of conventional oil production by 2035.

Discovering and unlocking those new resources will require a new generation of technology to be deployed at a global scale, and this technology must use existing infrastructure. That's not only a tough technical challenge but one accompanied by often overlooked challenges of industry culture.

Whether our innovation ecosystem can meet those challenges is an open question. The energy industry has a (perhaps undeserved) reputation for deploying innovations more slowly than others. Most important, it is not yet known whether the model of combining university research with venture capital—so successful in semiconductors and Internet services—will deliver real innovations in energy.

Part of the problem is that for energy technology to reach its full potential, it must be introduced, tested, and deployed at a scale attained only by major industry players invested in methods that already have a long track record. Conventional wisdom has it that those companies are not receptive to adopting new technology or working with emerging companies, but behind this reluctance are cultural differences that can be overcome. Working hard to master these differences has enabled our company to find experienced partners open to commercializing new technology.

NICK REDDYHOFF

The challenge stems from the fact that the skills required to raise venture capital and start a company are different from—sometimes contradictory to—the skills needed to partner successfully with a large energy company. The teams at startups working on energy innovation will need both sets of skills, and they need to know that the swagger that helps attract venture capitalists hurts more than it helps with people at the energy giants. These established players won't alter their existing methods without a high level of proof. To reach that point, energy entrepreneurs must patiently develop longer-term relationships with these companies.

The shale gas revolution illustrates that energy giants are quite capable of rapidly adopting new technologies that dramatically change the energy landscape. In just five years, the combination of horizontal drilling and hydraulic fracturing in unconventional shale resources has generated a surge in both proven reserves and production. Those techniques are being exported from Texas and Pennsylvania to the rest of the world.

Our vision is that future dramatic changes in energy resources will result when emerging companies connect with established players in an industry that has been the most competent in the world when it comes to deploying technologies at scale.

JOEL MOXLEY IS A MEMBER OF THIS YEAR'S TR35 (SEE P. 64) AND FOUNDER AND CEO OF FORO ENERGY, A STARTUP COMMERCIALIZING HIGH-POWERED LASERS FOR DRILLING AND OTHER USES IN OIL, GAS, AND GEOTHERMAL MARKETS.

GAMIFICATION

Toy Psychology

Using virtual points and badges to shape our behavior may not be as effective as some have hoped, says Judd Antin.

The world is in the midst of a gamification revolution—a mad dash to incorporate points, levels, and achievement badges into nearly every online and mobile experience. According to the hype, these "game mechanics" are a magic potion that can motivate anyone to do anything—purchase brand-name clothing, publicly share location information, or adopt healthy behaviors. Yet like many Internet revolutions, this one is tinged with irrational exuberance. Truly understanding what game mechanics can do requires significantly more nuance.

The intuitive idea is simple and appealing. Games are engaging, so making anything more gamelike should make it more engaging too. The scientific justification seems equally straightforward. Game mechanics invoke reinforcement learning; like B. F. Skinner's rats, we are repeatedly rewarded to produce the desired behavior.

Although behaviorist psychology is sound science, however, it is insufficient to justify gamification. Skinner's rats pressed a lever to get a morsel of food, and there is little debate about whether that constituted a reward. For human beings, what counts as a reward is much less clear. Points, levels, or badges are not inherently rewarding. The reward, when there is one, comes from underlying psychological phenomena such as social status, reputation, and group identification. Very little quality research has been done to show how game mechanics invoke these phenomena, and what the effects may be when they do.

When we look at game mechanics this way, it also becomes clear that they are unlikely to affect everyone in the same way. Some people actively seek status in the eyes of others, for example; other people are actually status-averse. Offering one-size-fits-all rewards may motivate certain people while putting others off. We need to understand more about the types of people who are motivated by specific gamelike rewards.

Another risk is that the extrinsic motivations supplied by game dynamics could crowd out motivations that are intrinsic to an activity. The most active Wikipedia editors, for example, are motivated by a shared investment in activities, interests, and beliefs that form a genuine connection among community members. The same is true in many online systems. Game dynamics, on the other hand, offer rewards that can be comparatively superficial and short-term. We know little about how gamification can undermine or support deeper, long-term motivation.

Game mechanics are, without a doubt, already effective motivators for some people in some contexts. Question-and-answer sites like Yahoo Answers successfully introduced points and badges long before the current craze. Well-designed incentive systems can enhance collaboration and bring more voices to the conversation. But game mechanics are not the magic potion they're made out to be. Gamification is still in its infancy, and much more research and development is needed to deliver its valuable potential. tr

JUDD ANTIN IS A MEMBER OF THIS YEAR'S TR35 (SEE P. 54) AND A RESEARCH SCIENTIST WITH YAHOO RESEARCH LABS.

What Actually Happened

Did social media matter in the Arab Spring? We sent a reporter to ask the revolutionaries.

What was the significance of social technologies such as Facebook and Twitter to the revolutions that overthrew the presidents of Tunisia and Egypt in January and February, and whose example continues to inspire protests in Libya, Syria, and Yemen?

The subject is disputed ground. In "Streetbook," beginning on page 70, John Pollock writes, "The Arab Spring has sharpened an acrimonious debate in the United States and Europe about the uses and importance of technology in regime change."

Writing in the *New Yorker* three months before Tunisia's President Ben Ali was ousted, Malcolm Gladwell insisted, "The revolution will not be tweeted." The platforms of social media are "built around weak ties" between virtual friends, he argued. Real revolutionaries, like the black civil-rights protesters who sat at a whites-only Woolworth's lunch counter in Greensboro, North Carolina, have "strong ties" to each other and are highly organized. Shortly before Egypt's president, Hosni Mubarak, fell from power, Gladwell returned to his theme, sneering, "Surely the least interesting thing [about the protests in Egypt] is that some of the protesters may (or may not) have at one point or another employed some of the tools of the new media to communicate with one another. Please. People protested and brought down governments before Facebook was invented."

Who were these credulous promoters of social media? One strange feature of the dispute is that skeptics felt the need to demonstrate their realism in the absence of many serious claims that either Tunisia or Egypt had experienced a "Twitter revolution." (Civil unrest in Moldova in 2009 was described as such at the time, because the protesters may have organized using the messaging service.) There were overheated claims about the role of Twitter, including some by ABC News. But if skeptics were responding to anyone, the writer they had in the back of their minds was the New York University professor of journalism Clay Shirky, whose book *Here Comes Everybody* Gladwell called "the bible of the social-media movement." There Shirky writes, "When we change the way we communicate, we change society."

The problem with the debate, conducted at this level of abstraction, was that it was "dumb," as another NYU professor of journalism, Jay Rosen, has bracingly observed. The dispute missed almost everything that was really interesting about the uses of social technology during the uprisings. To the editors at *Technology Review*, the more fruitful question was: *how* did Tunisians and Egyptians use social media during the uprisings?

We decided to answer that question by reporting what actually happened, and we sent Pollock, a writer who specializes in Africa, to interview the principals behind the region's youth movements.

What Pollock discovered was stranger and more inspiring than anything the debate between Western academics and journalists had suggested. In North Africa, social media seem to have made two things possible. First, they made *publicly knowable* experiences of tyranny common to many Egyptians and Tunisians but hitherto unacknowledged. Second, they helped revolutionaries organize continuous protests (in countries where the police had efficiently beaten, imprisoned, tortured, and murdered dissidents) by creating networks the regimes found difficult to suppress.

Pollock movingly describes how people used social media to circulate evidence of the regimes' atrocities. But his real scoop is the account by two secretive Tunisians, "Foetus" and "Waterman" of Takriz, an organization that rarely coöperates with journalists, of the tactics they employed to excite alienated street youth. Here, social media were overwhelmingly important. Foetus says, "Facebook is pretty much the GPS for this revolution. Without the street there's no revolution, but add Facebook to the street and you get real potential." The image the reader takes away is of very modern revolutionaries: seated in darkened rooms, hacking the streets from their laptops, before putting down their computers to join the riots.

Pollock's research did confirm one bias of Gladwell and his fellow skeptics: in the end, history happened on the streets. He quotes Nizar Bennamate, the 25-year-old cofounder of Morocco's February 20 movement, who is unhappy with the corrupt Makhzen, the elite of King Mohammed V's court: Bennamate says the streets are where the real action is, and where the real change occurs. "On Facebook and Twitter and social media we just speak [about] what happens," he says.

The virtual-reality scientist Samir Garbaya, of the Paris Institute of Technology, tested the interconnection of social media and the events on the street by writing a script using semantic search techniques that measured how long it took for Facebook posts to provoke responses (on the day Tunisia's president left office, just three minutes). He uses the portmanteau that lent Pollock his title. "Streetbook," Garbaya says, is "the transfer of the interaction from social networks to manifestation in the real world, on the street."

Tell me what you think at jason.pontin@technologyreview.com.

—Jason Pontin

MARK OSTOW

Synchronized satellites are being designed to bear large telescopes into space.

PHOTO COURTESY OF THE EUROPEAN SPACE AGENCY

Spain's aerospace sector has grown steadily over the past few decades. It now contributes to major international research and commercial projects around the world. Spanish companies are taking the lead in a number of international flight and space missions, including the European Space Agency's innovative Proba-3 mission. Proba-3 will facilitate the strategic deployment of increasingly sensitive astronomical research instruments.

SPANISH AEROSPACE

LEADERS AT EVERY ALTITUDE

FLYING AT GROUND LEVEL

Two helicopter pilots, members of a local police unit, sit side by side, working the controls with great care. Behind them, a third officer watches for any signs of danger. The helicopter vibrates as it hovers, and the three officers scan the crowded city for any signs of danger.

This latest simulation for the French-German-Spanish conglomerate Eurocopter's AS350 police helicopter (marketed in the United States as AStar) was designed by Madrid-based Indra, an international leader in information technology and a key player in the world simulation market. (Eurocopter's Spanish headquarters, in Albacete, recently celebrated the maiden flight of one of the most advanced transport helicopters, the NH90 TTH tactical transport, for the Spanish government. The Albacete facility will continue with flight testing, and should deliver the NH90 TTH to the Spanish armed forces in 2012.)

Indra's helicopter simulator, among the most innovative world wide for single-engine helicopters, can seat three in its simulation dome. It includes 10 projectors that cover 220 degrees of vision, almost surrounding the pilots. Indra delivered the first system of this class to American Eurocopter, the company's United States arm, at its Dallas center in October 2010. By December 2010 the simulator had been qualified by the Federal Aviation Administration. The simulator has since been employed, to take one example, in support of training for police departments around the country.

"The simulator is used for several types of training," says Juan Felip, Indra's director of simulation. "It's used to learn to fly the helicopter itself, and for skills refreshment, and for learning emergency procedures."

The addition of a third seat in the simulator offers the capability to train not just the pilots but a fully integrated mission of law enforcement or homeland security personnel, continues Felip, and is the first of its kind in the U.S.: "The shooter in the back uses a real gun that has been customized with a laser-pointing device. The simulator reproduces scenarios and situations the officers will have to face, and the instructor can evaluate their skills and capacities."

In addition to the standard day and night training, this is the first full-flight simulator qualified by the FAA that includes training simulations for pilots flying with night-vision goggles. The new simulator has attracted Eurocopter customers from around the U.S. and from abroad.

Indra has a long history in the field of simulation, and in the aerospace sector in general: the company has delivered more than 150 simulators to 15 countries, and is the only European firm that supplies simulators to the U.S. Navy. Its simulations range from commercial jets to military aircraft, to 360-degree air traffic control centers, among other mockups. In addition, the company's air traffic management systems are employed at airport and control centers in more than 90 countries, and facilitate the flow of millions of passengers each day.

In the past, simulators were primarily used for fixed-wing aircraft and for the larger, heavier (thus more expensive) sorts of helicopters. But as the cost of simulation technology has decreased relative to the price of helicopters, and as the world has grown increasingly concerned about the proportionally higher accident rates for helicopters, there's been an international demand for improving helicopter training tools—including simulators.

For helicopter flight training, simulation technology demands significantly richer visual data than jet simulations, because helicopters fly closer to the ground. "For example, you not only show buildings, but you can show a shooter within a building. You might display different moving cars, trucks, and other aircraft. The detail is much higher than is needed than for a simulator for a commercial jetliner," points out Felip. The resulting visual display must also incorporate information from nonvisual sensors, including the atmosphere and the humidity, to avoid so-called negative training, where pilots make mistakes because they practiced flights with incorrect or incomplete data.

Working with Eurocopter, Indra recently signed an agreement to deliver the first full-flight helicopter simulator to China. The helicopter fleet in China is growing, says Felip, and he expects that China will offer important business opportunities. In general, Felip sees the role of helicopter simulators growing everywhere: "The safety authorities, such as the FAA in the U.S. or the EASA [European Aviation Safety Administration], are pressing for more simulations for helicopters, and regulators are asking for a higher level of training."

A view from one of Indra's helicopter simulators in Dallas

FLYING LIGHT

Concerned with improving the fuel efficiency of planes, all the major aircraft manufacturers have been moving towards the use of composite materials in place of traditional metal parts. Composites, in particular carbon fiber–reinforced plastics, are materials in which thin filaments of carbon fiber are impregnated with plastic to form thin fabrics. These fabrics may be layered in molds, aligned to ensure optimal strength, then cured to fuse and set the materials together. The resulting material is light and strong.

Spain has a long history of expertise in the use of carbon fibers. Spanish companies first gained experience creating composite parts for the European space launcher, then moved from space into aircraft. These companies continue to supply expertise and major parts to all the major aircraft manufacturers, including Boeing and Airbus. "Spain started early in the manufacturing of composite components," says Rafael Quintana, general manager of the engineering company Sener's aerospace business unit, "first with smaller components, and now larger ones. This is why we now have in Spain [major] manufacturers for large parts for Airbus and Boeing… That comes from a long tradition of design for this technology."

Airbus is one of the companies that make up the multinational EADS, formed from Spain's CASA, Germany's DaimlerChrysler Aerospace AG, and France's Aerospatiale Matra. Airbus has been an international pioneer, continually expanding the use of composites in its aircraft. In fact, more than 50 percent (by weight) of the company's next generation A350s (the family of long-range widebodies) is made from composites.

Through its manufacturing and research facilities in Spain, France, and Germany, Airbus has also focused on developing both technologies to improve composite manufacturing speed and testing methods to guarantee that parts are free of defects, since problems with composite parts are often not visually obvious. The Airbus facility in Spain has concentrated on innovations in manufacturing technologies and on the assembly and testing of horizontal tailplanes and other major structural parts.

Vitoria-based Aernnova manufactures parts in both traditional metals and advanced composites for companies that include Airbus and Boeing. Amador Motos, Aernnova's director of innovation and technology, says the company regularly invests in the application of advanced materials and the development of manufacturing technologies for composites, which play an increasingly large role

PHOTO COURTESY OF INDRA

in Aernnova's business. Composite materials, points out Motos, have been used in primary and secondary structures in aircraft for decades, "but they have never been integrated into very large primary structures in commercial aviation" such as the wings and fuselage—the body—of the plane. So Aernnova, along with other leading companies and subcontractors, is "taking these processes [for manufacturing and certifying the structural integrity of the parts] and developing them for larger critical structures."

The challenge in increasing the use of composite materials lies not only in refining manufacturing techniques, but in certifying the process for manufacturing the structures, then detecting any flaws that occur during manufacturing, or later on during operation. Unlike metals, composites often spring back to their original shape after impact, so any damage may be invisible–but still serious. Aernnova, says Motos, is investing in what's known as Structural Health Monitoring, essentially creating a smart structure that can alert the operator to any damage to it. The company's engineers have developed a system of sensors to detect the location of damage and determine the type of damage that may have occurred, based on a given impact or stress. The system has been tested in flight and is now in the final stages of development, which includes reduction of its size, weight, and power requirements.

As a participant in the European Union's Clean Sky research program to develop state-of-the-art technology for future aircraft, Aernnova is partnering with other aerospace companies, universities, and research centers to design a new wing that will help cut down on the use of fuel. The airflow over a wing typically becomes turbulent, which adds to drag (and thus to fuel consumption). Wing designers strive to reach the ideal of laminar flow, that is, uninterrupted turbulence-free flow over the wing. "But it's hard to keep laminarity," explains Motos, "as it's affected by hard-to-control parameters, such as waviness from manufacturing or assembly, or [turbulence] induced by flight deformations."

The Clean Sky consortium is working on developing wings that can be manufactured and assembled within ever more precise tolerances, creating significantly better-controlled surfaces. This should help decrease turbulence and increase fuel efficiency.

Sener, which has major engineering and manufacturing projects in both the aircraft and space sectors, has been designing composite manufacturing installations for Airbus plants in Illescas, Spain and Stade, Germany. These installations will feature automatic production of wing "stringers," wing structures more than 100 feet long. "The challenge was to design a machine that's totally automatic," says Quintana, "starting from quality raw material, through cutting and molding, and then placing the structure in the precise location."

Quintana also points out the importance of guaranteeing the safety of composite parts in an industry more used to evaluating traditional metal. "Every new change requires a great deal of testing and proving before it's introduced in the market," he stresses. So Sener's researchers are modeling how composite materials behave under impact.

Aernnova's Motos explains that although his company still designs and builds metal parts for aircraft, the company's research focuses extensively on advanced materials. "We're betting on composites, and we're continuing to define lines and areas of research in the field," Motos says, as new Boeing and Airbus planes already employ about 50 percent composites in the plane by weight—more than 70 percent by volume. "We believe [composites] are here to stay."

Increasing the use of composites in large-scale structures is only one way to increase overall fuel efficiency. Madrid-based ITP, a top world producer of low-pressure turbines that power fans within aircraft engines, is making innovations in the design, manufacturing, and repair of their parts. The company recently designed a new lightweight turbine model, which is based on a new aerodynamic design and uses lighter materials. This model reduces carbon dioxide emissions by up to 15 percent. Instead of composite materials, these new engines incorporate advanced metal alloys that are light and can withstand extremely high temperatures, up to 1600° C.

Iberia Mantenimiento specializes in maintenance and overhaul of aircraft, for Spanish airlines and for international companies such as British Airways, Continental, and Royal Nepal; it is also certified by General Electric and Rolls Royce to repair their engines. Iberia Mantenimiento is developing new programs to detect corrosion of metallic structures, programs including sensors that can detect water before it causes corrosion, and others that discover damage to composite structures. Most recently, the company conducted a complete overhaul for Airbus, transforming a civilian aircraft into a military tanker, by dismantling the aircraft, completely renovating its internal structure, and adding additional sensors and

controls. "We completed the project in just 16 months, which I believe is the world record," says Saúl Martín, Iberia Mantenimiento's shared services and special projects manager.

SPACE TELESCOPES

Scientists want to deploy large telescopes into space to probe further into the nature of the universe, explains Diego Rodriguez, director of Sener's space department, but they're constrained by the size of the satellites. The ideal telescope would need to be a long, stiff structure, he points out, "and there's limited room in the launcher… With traditional technology, you can only use a structure that can be retracted and deployed."

A solution to such a challenge is a strategy known as formation flying, where two satellites would be launched and would then fly together; one might house, for instance, the lens of a telescope, and the other its detector.

This technique has already been employed in the aeronautics sector. In such a system, airplanes fly a set distance apart from one another and maintain a distance precisely. In the case of satellites, two satellites would be launched. One would contain an extremely accurate metrology system to monitor the location of the second to within a tenth of a millimeter, ensuring a perfect alignment between the lens on one satellite and the detector on another. "On the second satellite, you incorporate very small thrusters that provide extremely low but very accurate forces to compensate for the satellite's position, maintaining the alignment," continues Rodriguez.

While spacecraft have previously been launched that maintain positions relative to one another, none have yet achieved a sufficiently high degree of accuracy to unite the elements of a telescope.

Developing a successful formation-flying technology is the goal of Proba-3, a research project of the European Space Agency (ESA), and the first ESA mission to be headed by a Spanish company. Sener will lead the mission in primary partnership with GMV, a technology business group whose space headquarters are based in Madrid, and Madrid-based EADS CASA Espacio. (Two other members of the core team are the Belgian companies QinetiQ and Spacebel.) Sener will focus on control systems that will be continuously monitoring the satellites to maintain the appropriate distance. GMV, a top guidance, navigation, and control company, will design and implement the formation-flying system, which includes both onboard and related ground-based systems. EADS CASA Espacio, Spain's leader in the field of launchers, antennas, and satellites, will build one of the two satellites, which will incorporate new elements such as highly sensitive thrusters.

The deployment of two small satellites flying in precise location relative to one another will allow for the launch of much more powerful telescopes, x-ray sensors, or sensors that operate via radio frequency, to explore a variety of sources for information about the universe. Another such project, which the ESA is incorporating into the Proba-3 mission, is the study of the sun's corona, according to Gonzalo Galipienso, EADS CASA Espacio's political affairs director. For such a study, one of the satellites must act in much the same way the moon does during a solar eclipse, that is, it must use an instrument to block the body of the sun so that the second satellite's instruments can record the image of the solar corona.

Sener has designed composite manufacturing installations for Airbus in Spain.

PHOTO COURTESY OF SENER

EADS CASA Espacio recently developed instruments for an ESA research satellite that collects data for a project called SMOS (Soil Moisture and Ocean Salinity). The company is also developing two Earth observation satellites: Ingenio and PAZ. And GMV's work in the space sector has led that technology company to become the world's top supplier of ground control centers for commercial telecommunications operators, and among the leading suppliers of navigation and control systems.

"Formation flying is an extremely challenging technology," says Jorge Potti, general manager of GMV Aerospace. "This will surely enable exciting new missions that today aren't feasible."

Learn more at www.technologyreview.com/spain/aero

to market

BIOMEDICINE

Mobile Monitor

THIS CUFF, which plugs into an iPhone, is for people who want frequent blood pressure measurements. Users can choose either a single measurement or an average of three measurements per reading. The device stores and charts results so patients can share data with their doctors.

Product: Blood pressure monitor
Availability: Now **Price:** $129
Source: www.withings.com
Company: Withings

BRUCE PETERSON

ENERGY

Front-Wheel Drive

THE MOTOR and battery pack of this electric bicycle are built into the front wheel, and no control cables are needed because a wireless system throttles motor speed and applies a set of regenerative brakes. Top speed is 32 kilometers per hour, and the bike has a range of 20 to 40 kilometers, depending on how much pedaling the rider does.

Product: Shadow Ebike **Availability:** Now **Price:** $2,000 **Source:** shadowebike.com **Company:** Daymak

COMPUTING

Visual Gratification

INSTEAD OF gathering a crowd around a small screen or e-mailing links to download files later, users of this camera can share recorded video immediately via the camera's built-in projector. Videos can be displayed with a diagonal image size of up to 165 centimeters.

Product: CP40 Shoot 'n Share **Availability:** Now **Price:** $300 **Source:** www.shop3M.com **Company:** 3M

COURTESY OF DAYMARK (BIKE); 3M (PROJECTOR)

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NATIONAL INSTRUMENTS

BIOMEDICINE

Underwater Updates

RUNNERS, among other athletes, have long been able to monitor their heart rate while exercising. Now swimmers can too: an earlobe clip uses an infrared sensor to monitor blood flow. Heart-rate information is converted to speech, which is transmitted to the wearer's ear every few seconds or minutes via bone conduction.

Product: Aquapulse heart monitor **Availability:** Now **Price:** $150 **Source:** www.finisinc.com **Company:** Finis

ENERGY

Coming Out of the Shade

SOLAR CELLS collect power by means of a network of surface-mounted contacts, but this network blocks some of the sunlight falling on the cells. Thanks to a new technique for depositing metal onto the cells, this 245-watt panel has contacts a quarter the size of those in a conventional screen-printed network, letting more light through. Combined with a new surface-texturing process, this improves the efficiency of the cells by up to 10 percent.

Product: HiPerforma 245W module **Availability:** Now **Price:** Varies **Source:** ap.suntech-power.com **Company:** Suntech

ENERGY

Pay as You Go Solar

TARGETED TOWARD people in poor countries, this power supply, sold with a photovoltaic panel, provides electricity only after the user sends a code from a prepaid card over a mobile phone. The code unlocks the system until a set number of kilowatt-hours is consumed. Users buy cards until the cost of the entire system has been paid off, after which it unlocks permanently.

Product: Simpa solar energy system **Availability:** January 2012 **Price:** Starting at $150 **Source:** www.simpanetworks.com **Company:** Simpa Networks

COURTESY OF SIMPA NETWORKS (ENERGY SYSTEM); SUNTECH (HIPERFORMA); AND FINIS (HEART MONITOR)

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COMPUTING

Seeing Double

THIS LAPTOP has two 17-inch HD displays that slide past each other. The computer can also be operated in a narrower single-screen mode.

Product: gScreen SpaceBook **Availability:** Fall 2011 **Price:** $2,300 to $2,600 **Source:** www.gscreenlaptop.com **Company:** gScreen

COMPUTING

Speedy Storage

ALTHOUGH this gadget looks like a conventional thumb drive, it's actually a much higher-performance solid-state drive. It uses eight banks of flash memory, a solid-state drive controller, and a USB 3.0 interface to provide up to 100 gigabytes of storage, with write speeds about five to 10 times those of a typical thumb drive.

Product: USB 3.0 Express RC8 **Availability:** Now **Price:** $65 to $270 **Source:** www.supertalent.com **Company:** Super Talent Technology

COMPUTING

Camera Ready

THIS WEARABLE camera can record events continuously for up to 10 hours. If something interesting happens, pressing a button sends the last 30 seconds of video to Facebook, Twitter, or YouTube via the user's smart phone.

Product: Looxcie2 **Availability:** Now **Price:** $180 to $200 **Source:** www.looxcie.com **Company:** Looxcie

COURTESY OF GSCREEN (LAPTOP); LOOXCIE (CAMERA); AND SUPER TALENT TECHNOLOGY (USB)

Name
Peter Simonsen

Job Title
Design Engineer, Embedded Software

Area of Expertise
Renewable Energy

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ENERGY

Siphoning Electricity

DESIGNED FOR USE during blackouts or when electricity is expensive because of high demand, this supply system lets owners of Nissan Leaf electric cars power their homes with the energy stored in the car's batteries. Fully charged, a Leaf's batteries can supply an average Japanese house for about two days, or an American house for most of one day.

Product: Power control system
Availability: Spring 2012 **Price:** Not available
Source: www.nissan-zeroemission.com
Company: Nissan

COMPUTING

Swimming in Data

DROPPED into an aquarium, this USB-powered sensor will detect temperature and pH and ammonia levels. It comes with PC software that can predict if the water quality is likely to become a problem and send alerts to a smart-phone app.

Product: Seneye
Availability: Fall 2011
Price: $96 to $162
Source: www.seneye.com
Company: Seneye

COURTESY OF NISSAN (POWER CONTROL SYSTEM); SENEYE (SENSOR)

TURKCELL: FOSTERING INNOVATION AND ENTREPRENEURSHIP

In May 2011, Turkey's leading telecommunication and technology company Turkcell announced a partnership with Ozyegin University to launch an "enterprise factory," a business accelerator set to host up to 16 emerging entrepreneurial ventures each year. This is the most recent of Turkcell's efforts to encourage innovation and build partnerships with universities, both to support the company in providing new services to its customers, and to foster a culture of innovation throughout Turkey.

Promoting Entrepreneurs

Turkcell's recent focus on entrepreneurship in Turkey is a logical extension of the company's activities to date, according to company executives. The Turkcell Group has 60.4 million customers in nine countries, and is the leading mobile communications operator in Turkey and the third largest in Europe in subscriber numbers. "We're known for innovative services," says Alaaddin Alpay, head of the Entrepreneurship and Incubation Program, pointing out that the company has long promoted internal creativity. Turkcell has also developed an "ecosystem" of more than 300 partners, from companies such as Google and Facebook to local Turkish companies.

Not wanting to limit innovation to Turkcell and its partner companies, Turkcell's management "changed our approach towards a more open and innovative environment," says Ethem Eldem, head of product and partnership development. Turkcell's commitment to open innovation and entrepreneurship is relatively new in Turkey, Eldem highlights, and just within the past year it has observed a positive impact.

Competing Ideas

To promote participation from Turkey's next generation of innovators, in 2010 Turkcell sponsored the country's first mobile communications contest that invited applicants to develop applications for a variety of operating systems. The competition was organized into categories including health care, location-based services, entertainment, mobile gaming, and mobile marketing. Turkcell also recently sponsored the Technoldeas Business Plan Competition.

The top mobile application winners were healthcare related. One, a location-based service for Alzheimer's sufferers, tracks the movements of its owner, and sends an alert if the user falls and can't call for help. "Our application asks: 'Are you okay? Is there a problem?' and waits 10 seconds for his answer," says Gokberk Ergun, the application's creator. If there's no answer, the phone notes the location and emails it to a contact or health services.

Though none of the winning ideas have yet gone commercial, Gokberk says the competition spurred him to remain in the field; he now works as a freelancer, primarily testing media applications and games, and plans to start his own company. And a finalist team from the business plan competition has since formed a user-experience design agency, which is already consulting for Turkcell and other customers.

Focus on the Future

"Aware that the growing young generation will shape our future, we support young talents, university students who have a future in technology and new ideas that will grow our business," says Banu Sezen, head of the Turkcell Academy, emphasizing the importance of the university-industry collaborations it facilitates.

And among the ideas under development at the enterprise factory is a product for patients with sleep apnea, which can detect whether a patient's breathing has stopped. Another capitalizes on a consumer's shopping preferences to tailor an online shopping experience. Cenk Bayrakdar, head of new technology businesses, predicts that some of the new companies' products may reach consumers by 2012.

Turkcell has been building entrepreneurship partnerships locally and world wide. Over the coming year, the company will partner with Endeavor Turkey (a nonprofit organization focused on supporting entrepreneurship in emerging markets) and the MIT Enterprise Forum, and will sponsor entrepreneurship weeks at universities where representatives "will try to show that entrepreneurship is an alternative career path for graduates," explains Arzu Uraz, corporate citizenship specialist.

"All of these represent a series of pieces that together provide a stake in [the creation of] an open innovation environment in Turkey," especially for entrepreneurship in technology, says Eldem. "We had been perceived by young idea generators as a large company that wasn't easy to approach. But I think we've already altered this perception, and that we're now seen as a company supporting the entrepreneurial spirit in Turkey."

Alpay adds, "All efforts, such as building partnerships, running competitions, and organizing entrepreneurial events, take time to create sound business outputs. Turkcell has been investing in the creation of an environment that promotes entrepreneurship internally, and now it's time to help new businesses and entrepreneurs to flourish."

To learn more, please visit us at:
http://www.turkcell.com.tr/site/en

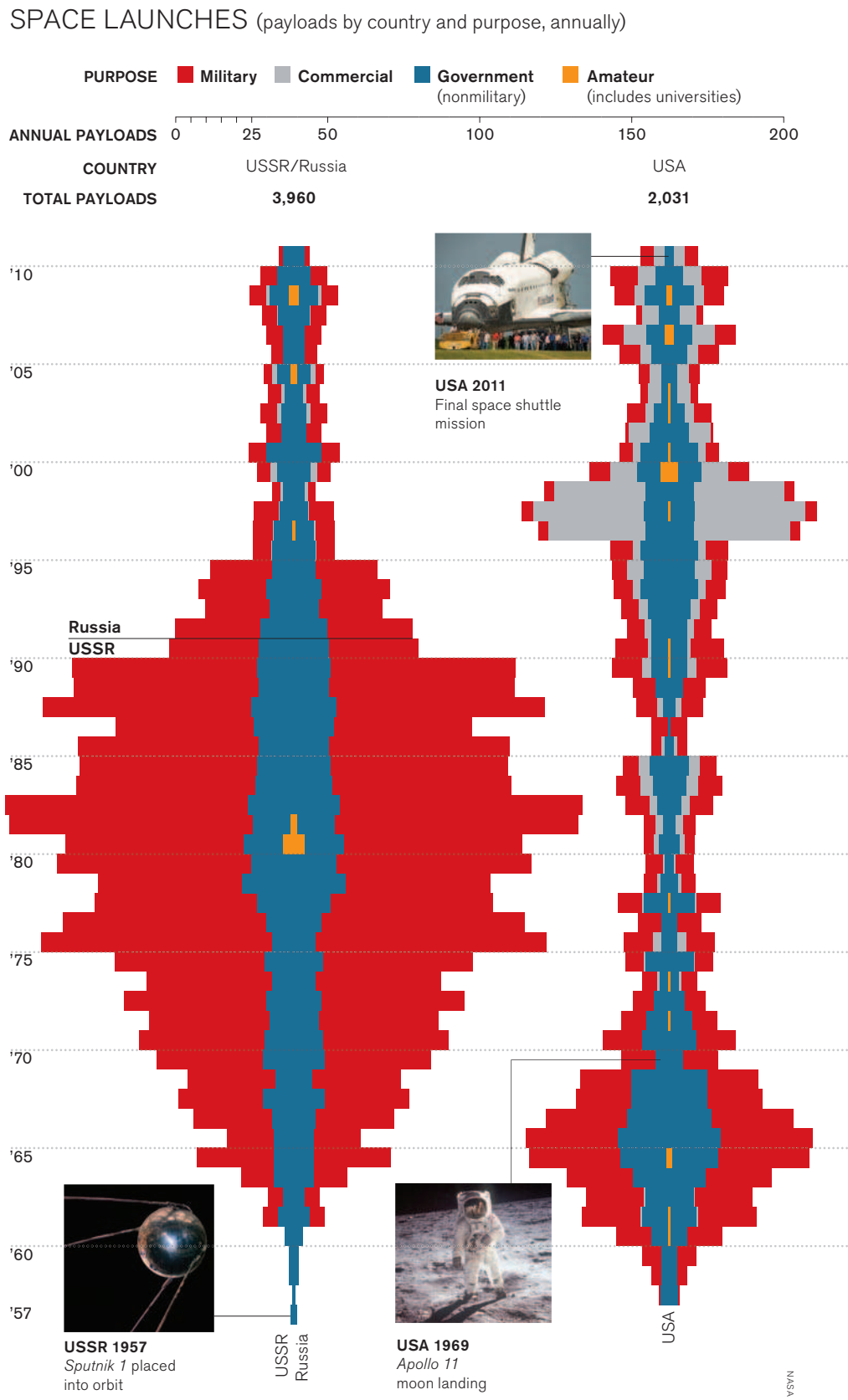
Space over Time

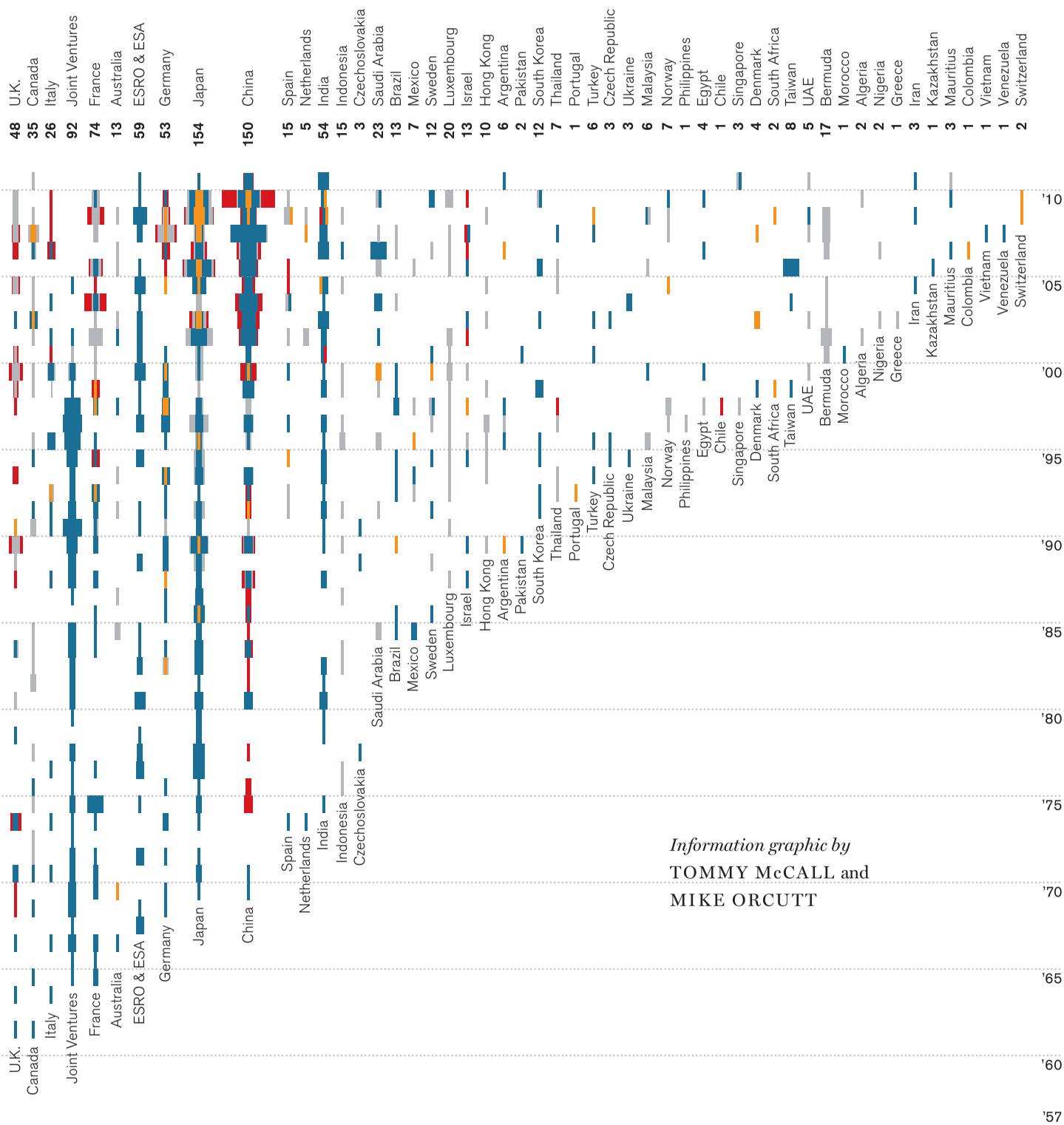
Human exploration is the most visible use of spaceflight, but business and defense satellites fill the sky.

The retirement of the space shuttles marks the end of NASA's human spaceflight program, at least for now. But human missions funded by the U.S. government have represented only a small part of the action in space.

Of the 7,000 spacecraft that have been launched into orbit or beyond, more than half were defense satellites used for such purposes as communication, navigation, and imaging. (The Soviet Union sent up a huge number, partly because its satellites tended to be much shorter-lived than those from the United States.) In the 1970s, private companies began increasingly adding to the mix, launching satellites for telecommunications and broadcasting.

This graphic groups payloads by the nationality of the owner. A satellite, a capsule of cosmonauts, or a deep-space probe would each count as one payload. The data, which run through July 2011, were drawn from hundreds of sources, including space agency documents, academic journals, and interviews. They were compiled by Jonathan McDowell, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics and author of *Jonathan's Space Report*, a newsletter that tracks launches. —*Mike Orcutt*





Notes: "Joint Ventures" refers to the multinational satellite consortia INTELSAT, INMARSAT, EUTELSAT, and EUMETSAT.
The European Space Research Organization (ESRO) was a forerunner to the European Space Agency (ESA), which was formed in 1975.

Q&A

Andy Grove

The former leader of Intel wants to see more manufacturing jobs in the United States—by any means necessary.

In an article he wrote last year in *Bloomberg BusinessWeek*, Andy Grove called himself "a onetime factory guy." It was a reminder that the 74-year-old retired chairman of Intel knows from experience how costly and risky manufacturing can be. Given these challenges, Grove argues, the U.S. government should do far more to nurture manufacturing, or else the country will face dire consequences.

For one thing, losing the ability to manufacture things domestically will make it harder for innovators to scale their ideas into products, he says. Indeed, although photovoltaic technology was invented in the United States, many key innovations in solar power are happening in Asia now, largely because the necessary manufacturing prowess is there. Second, he argues, only manufacturing can meaningfully reduce unemployment. That's why Grove thinks the United States shouldn't necessarily focus solely on "high-value" production of advanced technologies; it might also be wise to boost manufacturing of some lower-value goods.

In his *BusinessWeek* piece, he even called for taxes on goods made overseas, with the resulting revenue to be invested in American manufacturers. Such protectionist measures are unpopular with economists. But Grove remains convinced, as he told technology journalist Robert D. Hof.

_TR_: What prompted your concern about the decline of U.S. manufacturing jobs?

Grove: The incredible magnitude of job loss in the U.S. computer industry. In the 1970s, the U.S. computer industry had 150,000 workers. This became two million at its peak but now is back to 150,000. Meanwhile, computers went from a $20 billion to a $200 billion industry.

To have that happen and for us to continue to repeat the mantra that innovation and technology will save us, in the face of evidence to the contrary—that was why I wrote about this.

Aren't automation and other productivity improvements major reasons for this decline in factory jobs?

No. Notwithstanding productivity, most of those jobs still exist—just not here. You can correlate what happened in the U.S. completely to the rise of contract manufacturing [in which a company like Apple designs a product and hands off the production to another company]. One company accounts for 1.1 million computer manufacturing jobs—China's Foxconn.

Isn't it simply cheaper to manufacture in China?

First of all, try to find an analysis that tells how much cheaper. You can probably get whatever answer you want, depending on the assumptions you make. Is the local supply chain saving cost? How much of your support costs [expenses related to manufacturing, such as those incurred in product design or engineering] do you assign to labor in foreign countries? How much of the benefit of moving a plant offshore is from tax benefits from the host country?

The received wisdom is that "everybody knows manufacturing in the U.S. is dead." If you believe those things and act on them, they're going to be true. I think venture investments are influenced by the "everybody knows" factor before the first spreadsheet is run. And if you don't get the money to scale manufacturing here, you won't do it. And if you don't do it, your suppliers won't move to the United States either.

Do any other industrialized countries provide clues to how the United States might boost at least some kinds of manufacturing?

Germany managed—in complete contrast to the U.S.—to hold on to manufacturing and move it upscale. So they do precision manufacturing, like Mercedes. Siemens produces high-end imaging products and power technology. It's not that Germany has no problems. It's just that employment is not among them.

For that to be more feasible in the U.S., what needs to occur here?

I think the biggest enemy of manufacturing in the U.S. is the pseudo-knowledge that America is a bad place for manufacturing. This perception will keep manufacturing from happening and thereby ensure that the reality will fulfill the prophecy. I think for every example where companies, states, cities, governmental agencies do well on this issue, our government should find ways of drumming it into the consciousness of people who are considering building a plant or who are ready to enter a career which is *not* manufacturing-based. It is probably best to look at this as a major brand campaign.

You don't sound confident that the U.S. will recapture manufacturing jobs.

I think all of this is going to happen, but it will happen too late. In World War II, American manufacturing won the war, but even then, it took them two years to get moving, and that was a different world. I don't know any way to break the cycle except to plug away and create enough successes that you begin to raise doubts about the conventional wisdom. tr

Photograph by ROBYN TWOMEY

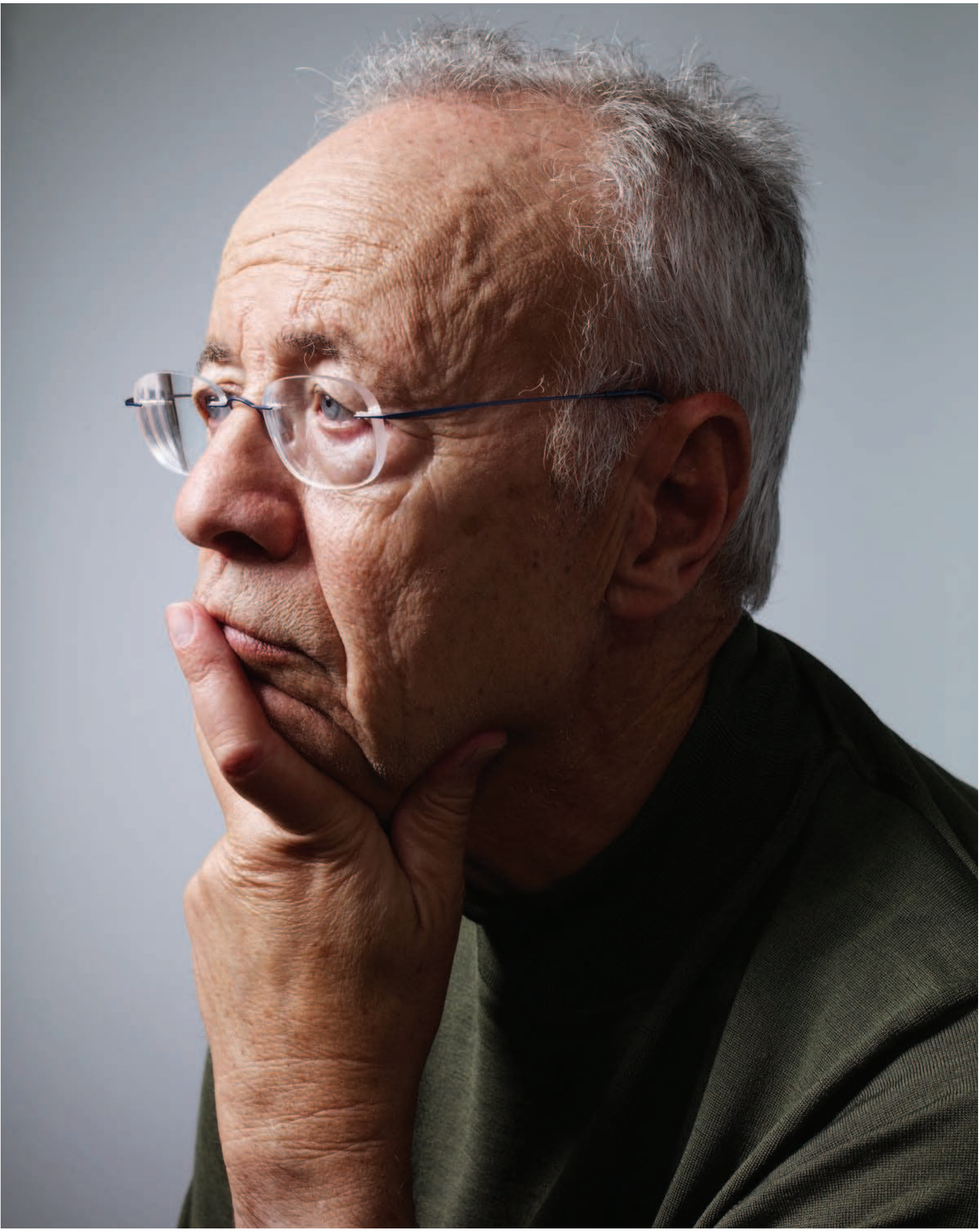
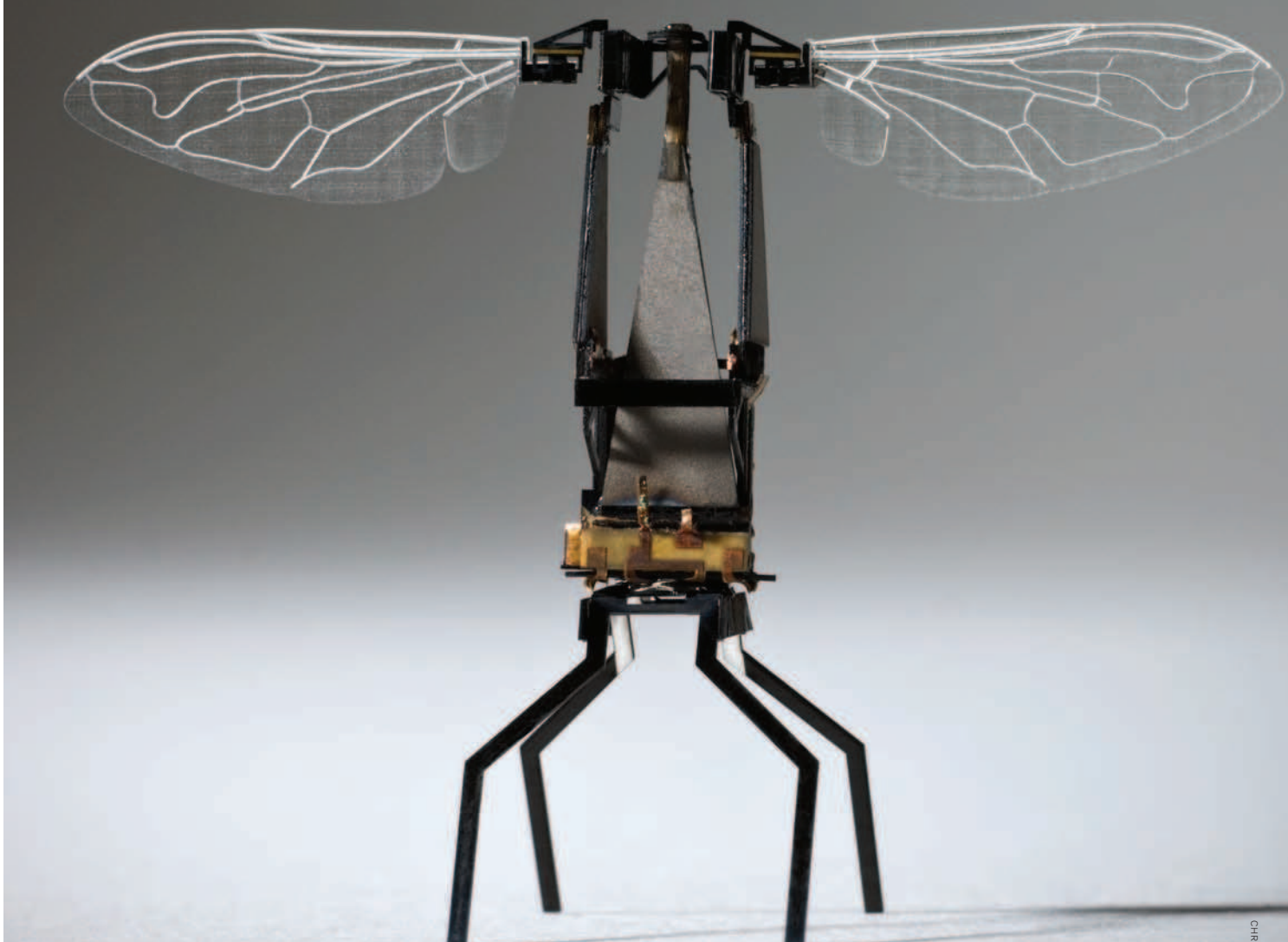


PHOTO ESSAY

Chasing Nature

As engineers begin to build tiny aircraft for tasks such as military-related surveillance and post-disaster search, they are turning to nature for inspiration. Conventional aircraft designs can be scaled down only so far, but birds and bugs are a fruitful source of alternative blueprints for cheap, agile miniature flying vehicles.

By TOM SIMONITE



CHRISTOPHER HARTING

RoboBees, like the one shown here, could be equipped with sensors and sent out after a natural disaster to collect environmental data or search for survivors, says their creator, Robert Wood, a professor of electrical engineering at Harvard University. For now, RoboBees can't fly unless they're guided by stiff wires and connected to an offboard power source. But Wood says that within about three years they should be able to fly unassisted. Such small robotic insects will be vulnerable, but they should be cheap enough to send on missions in large numbers with the expectation that not all will survive.

If swarms of small aircraft are to come into wider use, they will need to look after themselves. This quadrotor, with four helicopter-type blades, can navigate independently in controlled environments. It uses twin laser scanners, motion sensors, and an onboard computer to map its surroundings and the terrain below so that it can pick a safe landing place. Its builder, Maxim Likhachev of Carnegie Mellon University, says that future craft could be given high-level commands, such as "Go explore this building," without need for detailed directions.

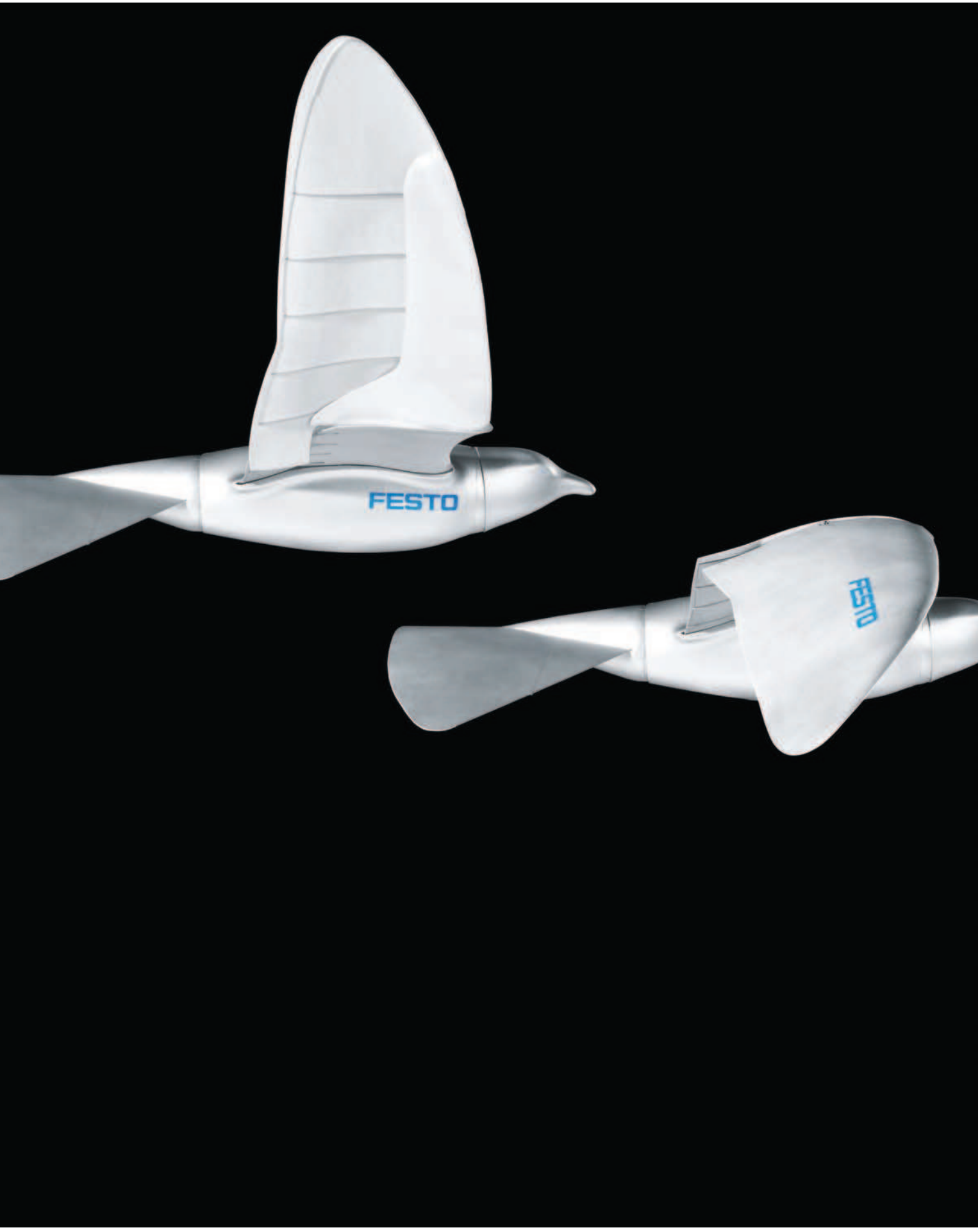
DOMINIC EPISCOPO

This hummingbird mimic can dart in and out of open doorways in an urban environment, flip in midair, and hold its position against winds of up to eight kilometers per hour. It was developed by defense contractor AeroVironment of Monrovia, California, to meet a call by the Defense Advanced Research Projects Agency for a small, agile reconnaissance craft. It can fly for 11 minutes, directed by a pilot using a live video stream from the camera visible on the hummingbird's chest.

AEROVIRONMENT

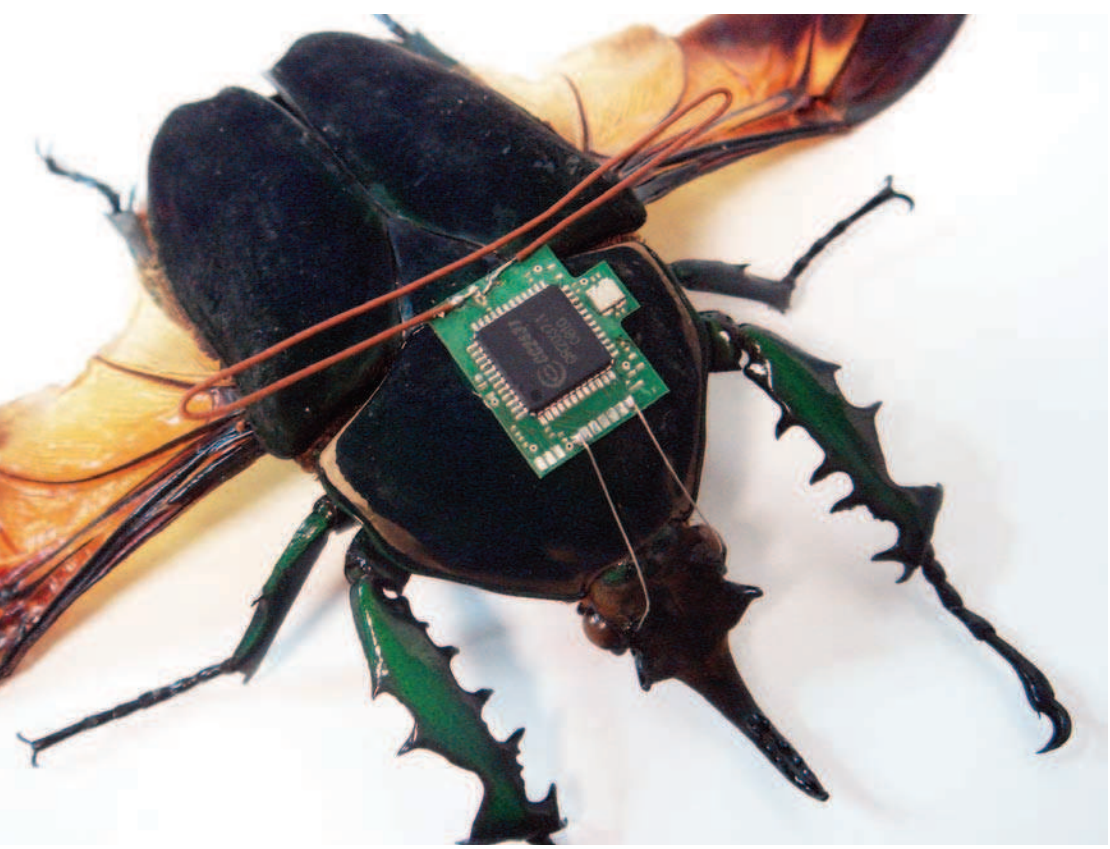
The wings of the SmartBird, built by the German robotics company Festo, closely mimic those of the seagull, from their two-meter span to their ability to twist for agility. While airplanes have separate structures and systems for lift, propulsion, and control, birdlike wings must handle all three at once. The SmartBird's wings twist as they flap up and down; varying the twist controls the flight. Birdlike designs are able to switch between soaring to conserve energy and flapping for takeoff and other maneuvers.

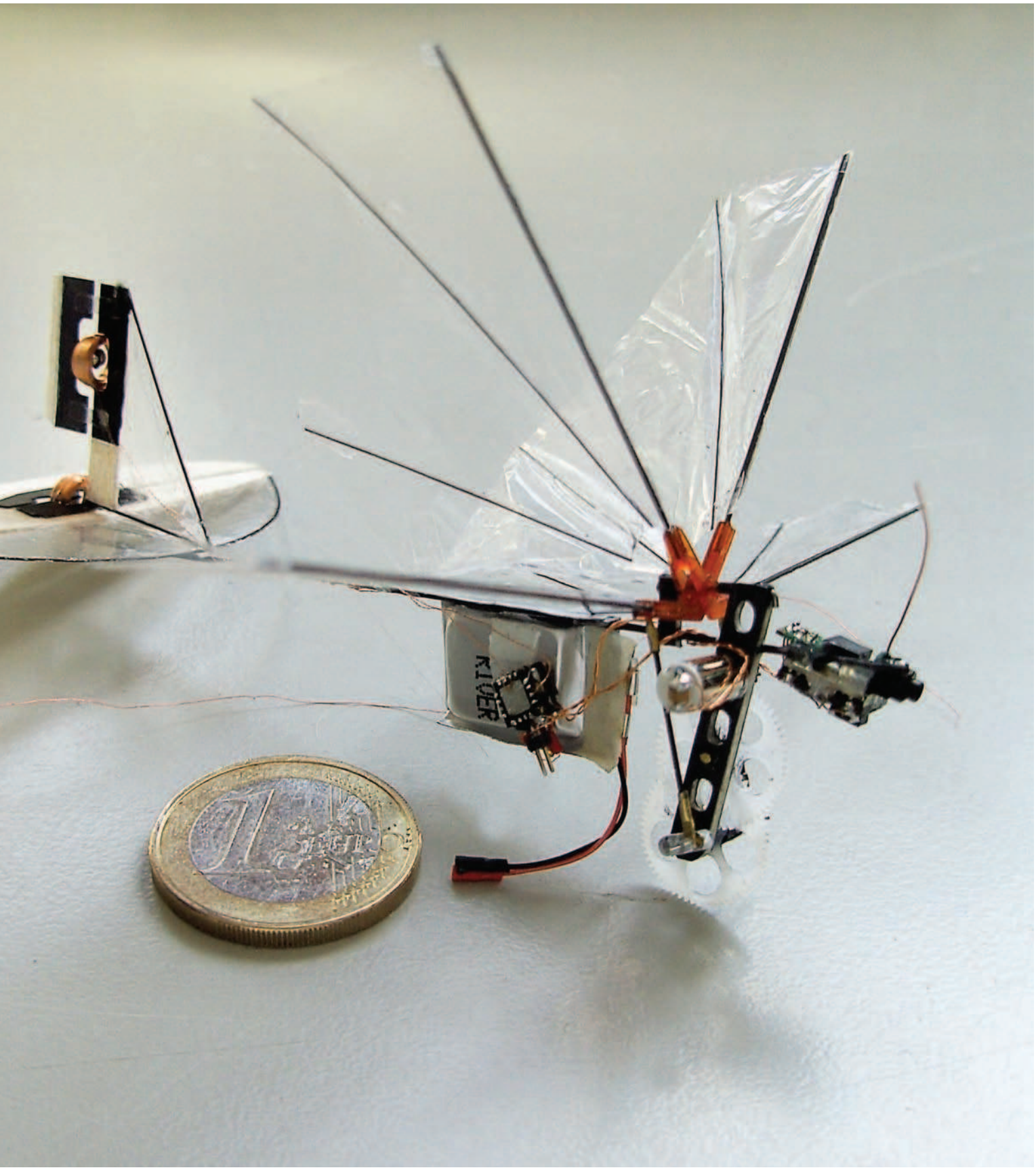
FESTO


FESTO
FESTO

Instead of working to build and control robotic insects, Michel Maharbiz and collaborators at the University of California, Berkeley, hijacked the real thing. This six-centimeter-long flower beetle is fitted with electronics that stimulate its brain and flight muscles. Signals delivered by radio waves command its flight. Maharbiz is working on miniaturizing the electronics to control smaller insects, such as houseflies.

The DelFly Micro, pictured at right next to a one-euro coin, is the smallest flapping-wing craft capable of free flight while carrying a camera and a wireless transmitter. It has a wingspan of 10 centimeters and weighs three grams. The team responsible for the DelFly, at Delft University of Technology, in the Netherlands, has achieved superior control by combining flapping wings with a conventional airplane-style tail.





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THE NEXT GENERATION OF TECHNOLOGY

35 Innovators Under 35

Selecting *Technology Review*'s yearly list of 35 innovators under the age of 35 is a difficult but rewarding process. We search for candidates around the world who are opening up new possibilities in technology, and then we seek the advice of a panel of expert judges before finally selecting the winners. We look for people who are tackling important problems in transformative ways. Sometimes that transformation comes from developing an entirely new technology, such as graphene transistors that could one day replace silicon devices in microprocessors. Sometimes it means using existing technologies in novel ways, such as creating an effective way for local businesses to advertise electronically or organizing social networks to build up a community of patients suffering from a disease. This is the 11th year we have chosen innovators under 35, and each year the young technologists, taken as a group, present a snapshot of how technology is changing. The 2011 TR35 are already shaping the future. We hope you find as much pleasure in reading about them as we did in writing about them. —*The Editors*

WINNIE WINTERMEYER

35

Humanitarian of the Year

STEVE MOORS

BIOMEDICINE

Paul Wicks, 30

Networking patients to combat chronic diseases

PATIENTSLIKEME

Each day, thousands of people around the world open an automated e-mail asking, "How do you feel now?" The e-mail's recipients belong to a social network called PatientsLikeMe, and nearly all have been diagnosed with a life-changing illness such as epilepsy, Parkinson's, chronic depression, or amyotrophic lateral sclerosis (ALS, also known as Lou Gehrig's disease). By answering this simple question, they are participating in an ambitious experiment that is challenging conventional ideas about health care and accelerating the pace of medical research.

The primary architect of this experiment is Paul Wicks, a neuropsychologist and the director of research and development at PatientsLikeMe. Wicks joined the company in 2006, two years after it was founded by MIT-trained engineers James and Benjamin Heywood and their friend Jeff Cole. Their original aim was to garner ideas for extending the life of the Heywoods' brother, Stephen, who had been diagnosed with ALS at age 29.

Stephen Heywood died in 2006, less than a year after PatientsLikeMe launched an online community where ALS patients could quantify and share details of their symptoms. But by then the site had demonstrated its potential to help its members. "We already knew we had something special," Benjamin Heywood recalls. "We were a well-resourced family with access to all the best doctors and scientists. But it was amazing how much we learned from our members from day one."

It was Wicks who shepherded the transformation of PatientsLikeMe from an online outpost for ALS patients into a thriving, global, passionately engaged community of people with more than 1,000 serious conditions, including cancer, diabetes, and HIV. The site gives patients access to powerful tools that were formerly available only to physicians and researchers, such as clinical assessment tests and algorithms that can predict, from the progression of the disease and other factors, how long someone is likely to live.


PLEASE
NO EATING
NO DRINKING
IN THIS AREA
Everyone loves a quitter.
LET'S WORK TOGETHER TO BE SMOKE-FREE.
patientslikeme

Some medical professionals questioned Wicks's willingness to put these tools into patients' hands, and they weren't as confident as he was that self-reported data had real value in clinical research. Wouldn't patients who could calculate their own prognosis become discouraged? Isn't self-reported data more subject to bias than traditional clinical trials? But Wicks's ideas have proved their value the old-fashioned way: with peer-reviewed studies in prestigious journals.

In April, Wicks and his colleagues countered claims by Italian researchers that a drug called lithium carbonate slows the progression of ALS. After a clinical study based on a small sample of patients showed promise for lithium in 2008, hundreds of PatientsLikeMe members began taking the drug, which can have serious side effects.

From the site's ALS community, Wicks assembled a sample of patients that was 10 times the size of the original study group, using an algorithm that matched lithium users with nonusers whose condition was progressing at a similar rate. The study revealed that despite many patients' enthusiasm for the drug, it was having no effect on the progression of their disease. Though the news about lithium was disappointing, it was also valuable. When a patient's life expectancy is measured in precious months, weeks, and days, being able to rule out an ineffective treatment can focus caregivers' efforts in more productive directions.

THE RIGHT BALANCE

Wicks's particular gift, say those who have worked alongside him over the years, is his ability to view medicine from every angle: from the perspective of the researcher who strives to understand a disease, the doctor who is working to treat it, and the patient who is struggling not merely to survive but to express individuality in the face of escalating physical challenges. "Paul has a unique ability to dive into the literature, learn about a disease, connect with the experts, talk with them at their level, assimilate that information, and then integrate it," says Benjamin Heywood. "Getting the right balance between the patient perspective, the clinical perspective, and the research perspective is key for us."

It's an ability that Wicks has been developing since his teens. After being inspired to study psychology by books like Oliver Sacks's *The Man Who Mistook His Wife for a Hat*, he began working as a summer tutor for autistic children. "Talking to the mothers of these kids as they fought for things like the right of their child to have a special-needs education was amazing," he says. These conversations helped Wicks, who was then only 17, learn how to speak effectively to people facing significant health issues and help them avoid being exploited by quacks.

By 2002, Wicks was working on his PhD at the Institute of Psychiatry at King's College London. When an online message board for ALS patients called Build lost its funding, he offered to moderate it as an unpaid volunteer, becoming a trusted intermediary between the Build community and doctors at King's College Hospital. "Some of our members would get angry and ask questions like 'Why do we need place-

2011 TR35 Judges

Ed Boyden*
Leader, Synthetic Neurobiology Group, MIT

Yet-Ming Chiang
Professor of ceramics, MIT

George Church
Professor of genetics, Harvard Medical School

James J. Collins*
Professor of biomedical engineering, Boston University

Stephen H. Friend
CEO, Sage Bionetworks

Javier García-Martínez*
Professor of inorganic chemistry, University of Alicante

Eric Horvitz
Principal researcher, Microsoft Research

Alex Huang*
Director, FREEDM Systems Center, North Carolina State University

Ed Lazowska
Professor of computer science, University of Washington

Johnny Chung Lee*
Rapid evaluator, Google

Nick McKeown
Professor of electrical engineering and computer science, Stanford University

Christopher B. Murray*
Professor of chemistry, materials science, and engineering, University of Pennsylvania

Dipankar Raychaudhuri
Professor of communications, Rutgers University

Chris R. Somerville
Director, Energy Biosciences Institute, University of California, Berkeley

Nimmi Ramanujam*
Associate professor of biomedical engineering, Duke University

John Rogers*
Professor of engineering, University of Illinois at Urbana-Champaign

Phillip Sharp
Institute professor, MIT

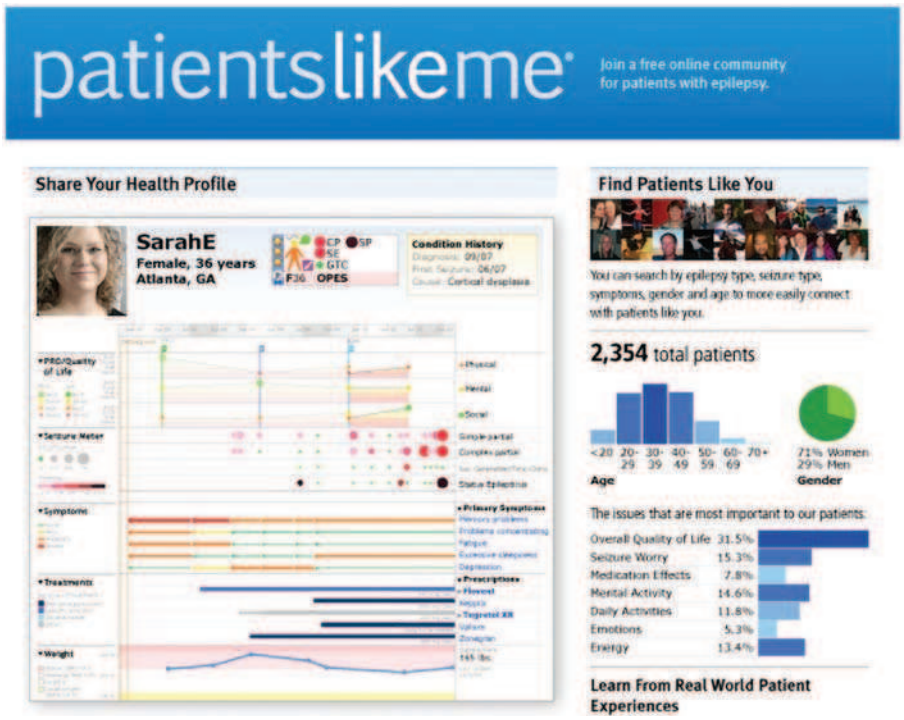
Bjarne Stroustrup
Professor of computer science, Texas A&M University

Jennifer West*
Professor of bioengineering, Rice University

Jackie Ying*
Director, Institute of Bioengineering and Nanotechnology

Ben Y. Zhao*
Associate professor of computer science, University of California, Santa Barbara

**Past TR100/TR35 honoree*



VERY PERSONAL PROFILE PatientsLikeMe users can track and share daily updates on many details of their condition, including their overall mood, the doses of medication they are taking, and the severity of their symptoms.

bos in clinical trials?' So I would go and ask the head of the clinical trials unit, he would explain it to me, and I would explain it to them," he says, stressing that "most of the benefit came out of the patients' interactions with each other." Build members swapped tips on using assistive technologies and offered support to those facing grueling medical procedures such as experimental stem-cell therapy.

Meanwhile, Wicks was driving hundreds of miles each week to make neuropsychological assessments of ALS patients in their homes. Many of them, he saw, were adapting to the challenges of their disease with creative tactics such as switching to electric toothbrushes when they lost their manual dexterity, or rigging up remote-control systems to accomplish tasks they could no longer perform themselves. "My favorite TV show as a kid was *MacGyver* [a show about an adventurer who would escape peril using items like duct tape and a Swiss Army knife], and these patients had MacGyvered their own solutions," he says. When Wicks heard about PatientsLikeMe from Build members, he saw an opportunity to aggregate and disseminate these solutions on a large scale.

> "Paul has a unique ability to dive into the literature, learn about a disease, connect with the experts, talk with them at their level, assimilate that information, and then integrate it."

PatientsLikeMe now has more than 110,000 members, from whom it solicits information about all aspects of their condition: their medical history, their course of treatment, the medications they're taking (including those they're using "off label," in unapproved applications), the adaptations they're making, and the impact of their diagnosis on their lives and those of their loved ones. (The company makes money selling aggregated member data to pharmaceutical companies like Novartis and Sanofi-Aventis.) Instead of encouraging its members to be guarded and private about the day-to-day realities of coping with serious illness, PatientsLikeMe advocates complete openness. Members can remain anonymous using avatars and pseudonyms, but many choose not to.

VIRTUAL VISITING

Gary Rogers, a 60-year-old kitchen designer who lives in North Carolina, joined PatientsLikeMe in 2010, seeking support after his diagnosis of multiple sclerosis and polymyalgia rheumatica, a painful inflammatory disorder. Before he became a member, Rogers doubted that participating in a social network would be very useful, but the site has helped him manage his health and stay connected with others.

"Each of us has a different set of symptoms to adjust to," he says. "Sharing these, as well as current treatment options, helps us decide which path to take and what we need to discuss with our doctors. Without PatientsLikeMe, I would feel alone and isolated, looking for information on impersonal research sites." He adds, "Most of us don't get out much, and being able to 'visit' with someone else helps relieve the cabin fever. The most important thing for me has been the friends I've made on the site and the emotional support they provide."

Wicks is pleased with what he's accomplished in five years, but he's still haunted by the social cost of incurable illness. "We need more people not being held back—not being dragged down, unable to participate because of health problems," he says. Defeating ancient afflictions like cancer and heart disease would create another challenge for society, he acknowledges: "the problem of everyone living to be 150." But that, he says, is a problem he would love to have. —*Steve Silberman*

WEB

Andrew Mason, 30

Electronic coupons for localized online advertising

GROUPON

Groupon is one of the fastest-growing companies of all time. Less than three years after CEO Andrew Mason launched it, it has more than 7,000 employees, operates in 43 countries, and is on pace to earn more than $2 billion in revenue this year. Its model is simple—it e-mails consumers with discount offers for goods and services in their cities—but it has taken off because previously there were few other cost-effective ways for small brick-and-mortar businesses to advertise to local customers.

Mason created Groupon by repurposing technology he'd developed in 2007 to help groups of people pledge to perform some civic action as long as a critical mass of users agreed to take part. The twist in Groupon was that the collective action would be buying something. Starting in Chicago, Mason began offering to deliver a daily promotional discount to consumers, who get the deal only if enough people sign up to make it worthwhile for the business. If not, the deal is off.

Groupon isn't close to being profitable yet, because it's spending hundreds of millions of dollars annually on marketing, sales-force expansion, and other things required to move on from startup mode. It also has to contend with new competitors hawking local bargains. Mason plans to adapt with, for instance, a mobile service called Groupon Now that lets people see offers near where they happen to be. Groupon Now is also more flexible for businesses, which can offer bargains at targeted times, such as when sudden cancellations leave a restaurant with empty tables to fill. *—Brian Bergstein*

COMPUTING

Pieter Abbeel, 33

Robots that learn from people

UNIVERSITY OF CALIFORNIA, BERKELEY

INSTEAD OF programming robots to handle each step of a new job, Pieter Abbeel, an assistant professor at UC Berkeley, has created robots that can observe humans demonstrating a task and then mimic them, or learn from pictures how to handle a piece of flexible material they've never seen before. His robots have learned to perform flying acrobatics, tie surgical sutures, and neatly sort socks.

Abbeel's key innovation was to program the robots so that they can reliably infer the underlying intent of their instructors, filtering out the "noise"—irrelevant variations, or even slight mistakes, in the instructors' demonstrations. Each robot is usually shown around 10 demonstrations before it can extract general rules of behavior. Even without an instructor, it can sometimes work out what to do. For example, Abbeel taught one robot how to fold laundry by giving it some general rules about how fabric behaves, and then showed it around 100 images of clothing so it could analyze how that particular clothing was likely to move as it was handled. After that, the robot could fold towels and sweaters without further instruction. *—Kristina Grifantini*

RUDY ARCHULETA/REDUX

WINNIE WINTERMEYER

HELPING HANDS Pieter Abbeel has programmed robots to learn how to perform tasks without detailed instructions. This robot can fold laundry, while others can fly model helicopters or tie sutures.

COMPUTING

Alina Oprea, 34

Guaranteeing cloud security

RSA LABORATORIES

PROBLEM: Cloud computing offers numerous advantages to businesses and individuals by enabling them to store data and run websites on remote computers rather than ones they own. But many hesitate to use the technology for fear of what might happen if a cloud provider's systems aren't secured properly or break down.
SOLUTION: Software created by Alina Oprea, a researcher at RSA Laboratories in Cambridge, Massachusetts, can guarantee users that their data hasn't been tampered with and won't become inaccessible. For her 2007 PhD thesis, she developed a digital fingerprint capable of quickly verifying that data stored in the cloud hasn't been maliciously altered or accidentally corrupted. Then, at RSA, Oprea helped create HAIL, a technology that lets users divide data among multiple cloud providers in such a way that if one provider goes offline, the missing information can be reconstructed from the data stored by the others.

Next she helped lead the development of HomeAlone, which guards against an insidious threat in cloud computing: when users buy remote computing power, they often share server space with other customers, offering an opportunity for potential hackers. Many cloud providers let customers pay extra for their own private servers to avoid this risk. HomeAlone lets customers who choose that option verify that the data is indeed isolated and no one is snooping on their space in the cloud. —*Stephen Cass*

HIGH-SPEED ACTION This image was generated in a fraction of the time required by traditional graphics software.

COMPUTING

Kun Zhou, 33

Creating movie-quality graphics in real time

ZHEJIANG UNIVERSITY

Thanks to Kun Zhou, computer games will become more realistic and animated movies will reach cinemas faster. The Zhejiang University computer science professor has released software capable of rendering movie-quality scenes using graphics chips of the sort that most PCs use to create comparatively crude images.

These chips, known as GPUs, perform many relatively simple computations in parallel. While this design is adequate to synthesize images for today's computer games, it wasn't seen as a good fit for the complex algorithms required to create the truly photorealistic images produced by animation and special-effects studios. But in 2009 Zhou developed a programming language that could efficiently break up these algorithms in a way that suited GPUs. He used this language as the foundation of a rendering system called RenderAnts, which generates images more than 10 times as fast as traditional software. A Chinese animation studio is already using an early commercial version of the software to increase the quality of its television productions, and Zhou is collaborating with the Frankfurt-based gaming studio Crytek—maker of the popular Crysis series of games, which are often used to benchmark the graphics performance of PCs—to improve the realism of its products.

Making games more realistic while keeping them fast enough to respond instantaneously to a player's actions is a personal goal for Zhou. He says he got hooked on games as a young engineering student and has been trying to overcome their limitations ever since. *—Peter Fairley*

BIOMEDICINE

Yemi Adesokan, 34

Using fast DNA sequencing for medical tests

PATHOGENICA

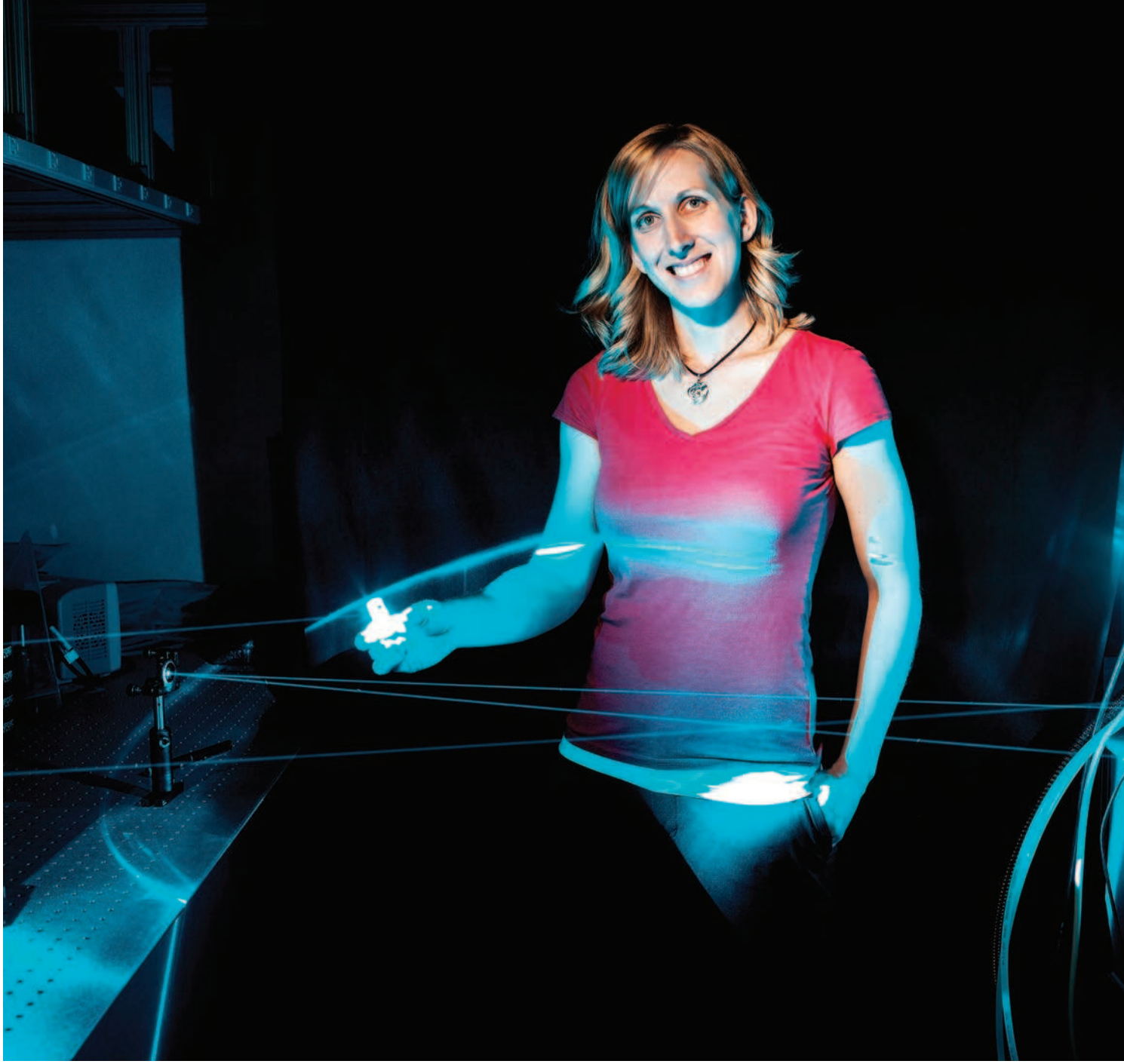
DIAGNOSTIC TESTS being developed by Yemi Adesokan and his company could let physicians quickly and cheaply pinpoint features of a patient's infection, such as whether it is resistant to certain antibiotics, and prescribe the most effective treatment.

In 2009, as a postdoctoral researcher at Harvard, Adesokan cofounded a startup called Pathogenica with the goal of developing commercial applications of DNA-sequencing technologies. Adesokan, the CEO, expects to create a market for tests that use sequencing to detect the microbes behind infections. To identify these pathogens today, scientists must use expensive DNA tests or grow the microbes from a sample—a slow process that doesn't work for many bacteria. And both methods often fail to detect small differences in DNA that can have a huge impact on the organism's virulence and resistance to drugs. Pathogenica's technology can pick out specific regions of a pathogen's genome, such as the genes involved in its ability to infect its host, and sequence many of these regions simultaneously. It minimizes the amount of sequencing, so Pathogenica's approach will be cheaper, faster, and more precise than existing tests, says Adesokan.

Pathogenica's initial efforts have focused on detecting the microbes that cause urinary-tract infections. Its researchers are also developing tests to analyze how microbe populations change when someone is treated with new antibiotics or antivirals. Because the technology can detect small changes in DNA, it may be able to reveal early on if a population of microbes is developing resistance to a drug. *—Emily Singer*

COURTESY OF KUN ZHOU

MARK OSTOW



MATERIALS

Jennifer Dionne, 29

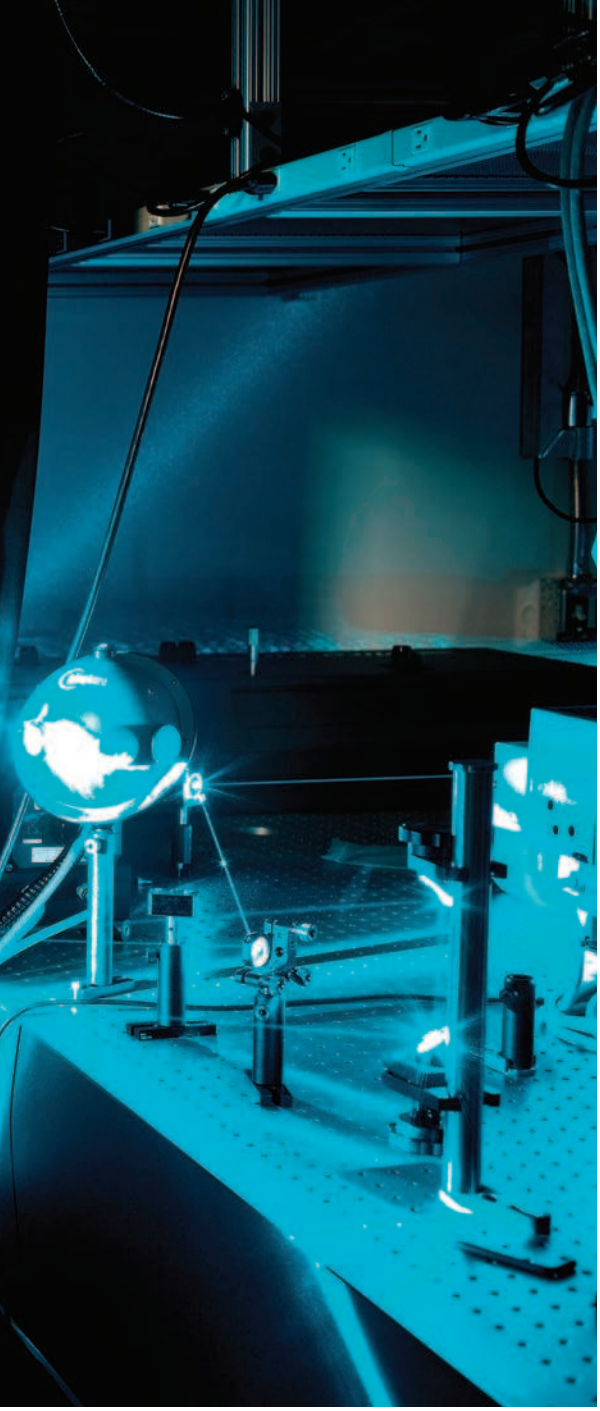
Solar cells that see more light

STANFORD UNIVERSITY

AS IT PASSES THROUGH a solution in a small vial, the green light from a laser pointer in Jennifer Dionne's hand turns into a sparkling blue beam. By making materials that perform a similar color conversion on sunlight, Dionne hopes to boost the output of solar cells and improve the economics of solar power.

Thirty percent of the sun's light is wasted in even the best of today's solar cells because this near-infrared light has too little energy to interact with materials in the cells. Other solar researchers have tried to do what Dionne is doing—"upconversion"—by combining two dyes that interact with each other to convert two low-energy photons into one high-energy photon. But Dionne is taking a new approach that could improve upconversion efficiencies by as much as 50 per-

GABRIELA HASBUN



cent. She added metal nanoparticles to an existing combination of upconversion dyes; the particles shine more light on the dyes and get more converted light out of them.

It's an early demonstration, but solar-cell maker Bosch is working with Dionne to develop dyes that perform the upconversion. The technology could be incorporated into solar cells in seven to 10 years.

—Katherine Bourzac

AISHWARYA LAKSHMI RATAN, SUNANDAN CHAKRABORTY

COMPUTING

Aishwarya Ratan, 30

Converting paper records to digital in real time

YALE UNIVERSITY

Beginning in 2009, while working with Microsoft Research India, Aishwarya Ratan spent 15 months figuring out how to help local microcredit co-ops, which often struggle with handwritten entries that are illegible, incorrect, or incomplete. Her solution combines digital technology with the familiar paper notebooks that villagers prefer. Co-op members use an electronic ballpoint pen to write in ledgers placed on a slate equipped with software that recognizes handwritten numbers. The slate provides feedback on whether the records are complete and legible, stores them in a database, and gives real-time balance updates, both on a screen and verbally in the local language. The database can be shared with the nongovernmental organizations and banks that back each co-op.

In field tests, the hybrid slate yielded entries that were 100 percent complete and made record keeping faster while letting co-op members retain the paper records they are comfortable with. The potential of the system is tremendous: microfinance co-ops serve 86 million Indian households. High-quality record keeping could make them more efficient, helping members save more and repay faster, and it could allow the co-ops to borrow more easily from banks.

In June, Ratan became the director of the Microsavings and Payments Innovation Initiative at Yale University, which as part of its mission studies how technologies can help the poor financially. Meanwhile, the NGO that Ratan was partnering with continues to test the slate in villages. *—Prachi Patel*

PAPER TRAIL Designed to help rural microcredit lenders keep better records, this slate digitizes entries as they are handwritten in a ledger, then displays and speaks the recorded amounts.

MATERIALS

Christopher Bettinger, 30

Tailoring polymers for biodegradable implants

CARNEGIE MELLON UNIVERSITY

As a graduate student at MIT, Christopher Bettinger created strong, rubbery polymers that mimic natural tissue and can be tailored to break down after anywhere from two months to two years. For Bettinger, the hardest part was making sure the molecular building blocks of his polymers were interconnected enough to yield a material that held its shape but not so strongly interconnected that the result was brittle. He initially used the new polymers to make scaffolds for laboratory-grown tissue. Now, as an assistant professor at Carnegie Mellon University, Bettinger is using them to produce degradable catheters and drug-delivery systems that he's testing in animals.

As part of his postdoctoral work at Stanford in 2009, Bettinger also created a biodegradable semiconductor for electronics used in temporary medical implants. Simple electronic circuits constructed from biodegradable materials could lead to drug-delivery devices and nerve-regeneration scaffolds that a doctor would trigger with radio frequencies from outside the body. Once therapy was complete, the devices would disappear without a trace.

—Prachi Patel

COMPUTING

Dan Berkenstock, 31

Cheaper satellite pictures

SKYBOX IMAGING

DAN BERKENSTOCK, cofounder and chief product officer of Skybox Imaging, wants to let "anyone know what's happening anywhere in the world at any time." Next year the company plans to launch the first of what it hopes will be a constellation of 12 to 24 satellites taking high-resolution pictures of Earth. Each satellite should cost about a tenth as much as the $250 million to $500 million imaging satellites operated by companies like DigitalGlobe and GeoEye.

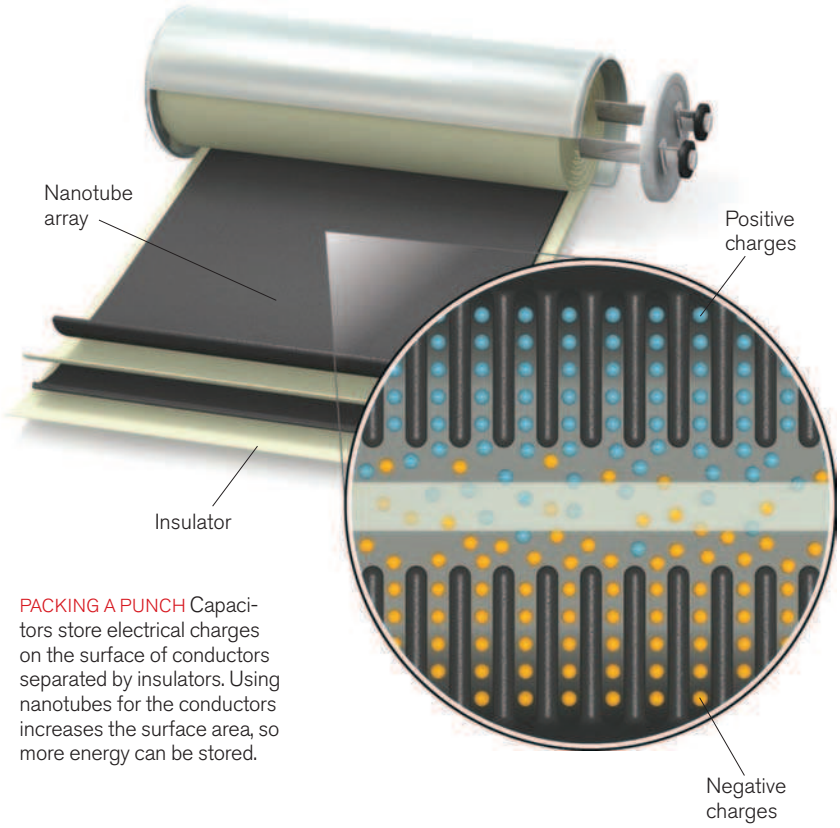
Currently, so few commercial imaging satellites are in orbit that it can take days or even weeks to get pictures of a location—and there will be only one per day. By placing multiple satellites in multiple orbits for the cost of a single traditional satellite, Skybox plans to realize something closer to Berkenstock's vision of anywhere, anytime coverage: it could photograph nearly any spot on the planet up to three or four times a day, weather permitting. (Skybox's license from the U.S. government takes security and privacy concerns into account: the satellites will have one-meter resolution—enough detail to identify a crowd but not an individual.)

The secret to the low cost of Skybox's satellites is their size: each one is about as big as a large trash can, rather than a minivan. With smaller, more modern components than those typical in the conservative aerospace industry, they're cheaper to build, and less expensive rockets can be used to launch them. Skybox is hoping to recoup the cost of the constellation by expanding the market for fresh satellite imagery beyond the government and the military. Berkenstock is working on tools for storing and classifying petabytes of data—tools that financial analysts, for example, could use to get daily counts of the cars in the parking lots at thousands of retail locations. *—Stephen Cass*

ELI MEIR KAPLAN

EYES UP Dan Berkenstock is developing new, smaller imaging satellites, along with software that will automatically analyze the images for useful information.

TOBY BURDITT



PACKING A PUNCH Capacitors store electrical charges on the surface of conductors separated by insulators. Using nanotubes for the conductors increases the surface area, so more energy can be stored.

ENERGY

Riccardo Signorelli, 33

Cheap nanotubes for ultracapacitors

FASTCAP

Hybrids make up less than 3 percent of passenger-vehicle sales, largely because they cost so much. Expensive batteries account for much of the premium price, but Riccardo Signorelli is developing cheap ultracapacitors that could replace them. Hybrids based on his technology could be inexpensive enough to start paying for themselves in fuel savings after one to two years.

Ultracapacitors, which store actual electrical charges rather than storing energy chemically, are far more durable than batteries and work well in cold weather. But conventional ultracapacitor cells store only a relatively small amount of energy, so it would be expensive to use them in the quantities required to power a car. Signorelli has developed new ultracapacitor materials that use arrays of carbon nanotubes to form electrodes with a large surface area, tripling the amount of energy that each cell can store. In 2008 he founded a company called FastCAP to commercialize the technology (he is currently CEO), and by now he's raised $7.6 million. The company has focused on bringing down the high cost of nanotubes through cheap manufacturing techniques based on those used in the solar-cell industry. All told, the ultracapacitors should be able to store energy at less than half the cost per watt-hour of current technology. Signorelli expects that hybrids with his ultracapacitors will start appearing within five years. *—Kevin Bullis*

MATERIALS

Dae-Hyeong Kim, 34

Stretchable electronics for medical devices

SEOUL NATIONAL UNIVERSITY

SURGERY FOR a common type of cardiac arrhythmia could be quicker thanks to Dae-Hyeong Kim, an assistant professor of biological engineering at Seoul National University. Kim has built a balloon catheter that can expand to one centimeter in diameter and is equipped with 150 nanometer-thin metal wires that connect to 13 electrodes. Pushed through blood vessels, this device allows a surgeon to detect electrical misfires in 13 patches of heart tissue at a time and use radio energy to blast any patch where a misfire is found. Previously, surgeons had to detect misfiring regions one by one with a single wire and then zap any problems with a second wire.

The catheter is just one application of Kim's bendable, stretchable high-performance silicon electronics, which could be used in everything from prosthetic neural interfaces to brain implants for controlling Parkinson's. Devices made from the materials are sensitive enough to detect subtle changes in human physiology, while the wiring is tough enough to deliver cell-zapping energy.

Kim's catheter is now being tested in pigs. Another of his devices, a flexible sheet of electrodes that can be draped over delicate tissues, has been used to map abnormalities in the brains of epileptic cats. Both are under development by the startup MC10. *—David Talbot*

EMILY COOPER

BRUCE PETERSON

MAP AND ZAP Multiple diseased patches of heart tissue can be detected and cauterized with this catheter's flexible electronics.

COMPUTING

Jernej Barbič, 34

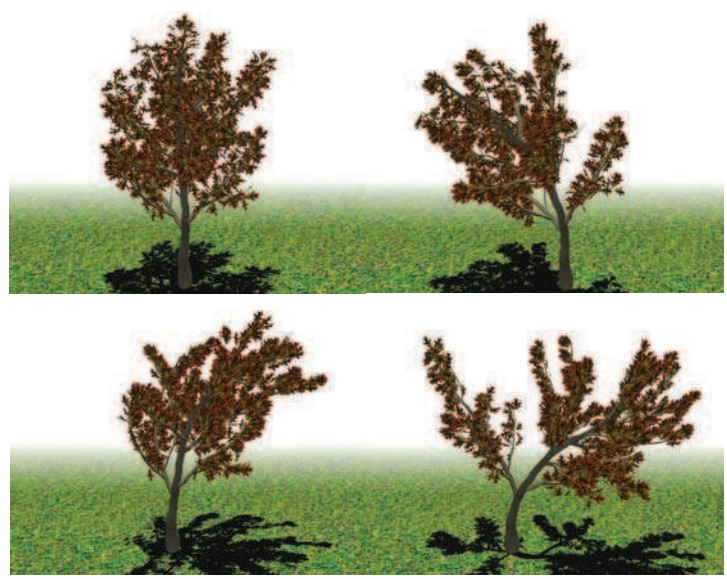
Speeding up simulations of complex objects

UNIVERSITY OF SOUTHERN CALIFORNIA

Engineers and animators use computer simulations to model the ways objects bounce, bump, and change shape under external forces. Until now, these simulations were too complex to run in real time, but Jernej Barbič has developed a way to make them run tens of thousands of times faster than previously seemed possible—fast enough for engineers to be able to interact with a model and see it respond instantly, allowing them to experiment with designs as never before.

Barbič translates models with millions of parameters into versions that have just tens or hundreds but are still accurate. He created software that can automatically identify which parameters are the most important and determine how these can be combined to reduce their number.

His latest experiments connect models to haptic interfaces that allow a user to literally feel what's happening in the virtual world. Producing a realistic physical sensation of movement takes approximately 1,000 updates per second. "That's infeasible without Jernej's approach," says Adrien Treuille (a member of the 2009 TR35), a professor at Carnegie Mellon University. Barbič is now in talks with the French company Haption to commercialize the technology. He says that because his techniques make it easier to quickly test and revise designs, products could "be made faster and turn out cheaper and safer." —*Tom Simonite*



SIMPLIFY, SIMPLIFY An accurate digital model with fewer parameters makes it possible to simulate in real time how a tree moves when subjected to wind.

35

WEB

Judd Antin, 32

Learning what drives online collaboration

YAHOO RESEARCH

"WHEN YOU LOOK at YouTube, Flickr, Facebook, or similar services, there's so much collaborative work going on. But we don't really understand why," says Judd Antin, a research scientist in the Internet Experiences Group at Yahoo Research. Indeed, many of the marvels of the Internet age, such as Wikipedia, have come from rethinking traditional ideas about how workers should be organized and rewarded. Antin is finding out what motivates people to participate in such projects, in hopes of attracting the broadest possible spectrum of contributors and decreasing the likelihood that the projects will fizzle out after the novelty wears off.

One finding: using game-like approaches and software—for example, to prompt people to reveal their location to advertisers—might be overrated as a way to shape behavior. The popular tactic of rewarding people with points and badges doesn't motivate them for long on most websites, Antin says.

But he still believes some game dynamics will remain effective in the long term, and he's working to figure out what those are. He also wants to learn how motivation varies across cultures. With those tools, he hopes, organizations will be able to consistently nurture the Web's collaborative spirit and turn it to good use.

—Erica Naone

WEB

Xiao Li, 32

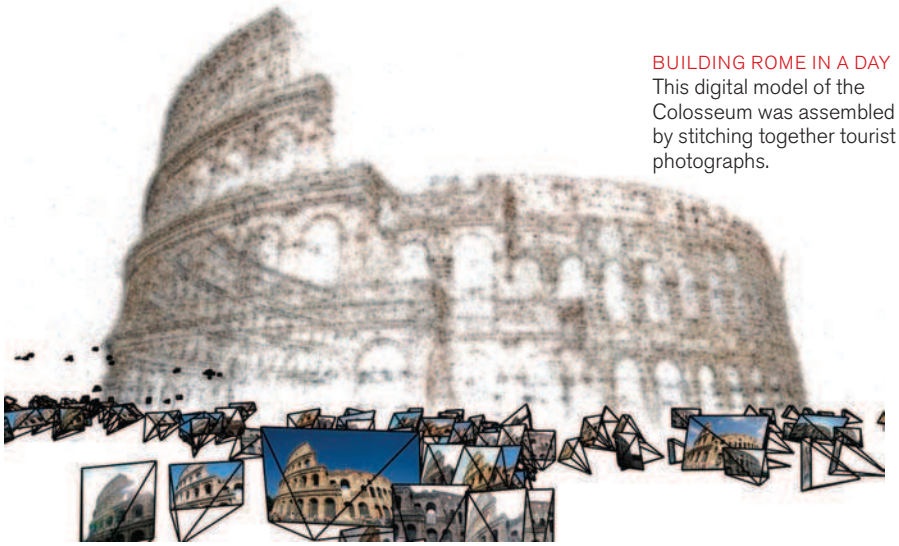
Anticipating what Internet users are searching for

MICROSOFT RESEARCH

Search engines are pretty good at matching keywords with relevant websites. Xiao Li is helping teach Bing, Microsoft's search engine, to go a step further: figure out the specific task a user is trying to tackle with a query, whether it's buying a digital camera or booking a hotel room, and return the most useful results related to that task.

Li created software that can automatically crunch through terabytes of Bing's logs. By building relationships between keywords, the links people click, and the type of information presented on Web pages, the software can predict what a user is trying to accomplish, even if unfamiliar search terms are used. Once Bing determines the intent of a query, it can pass the query to one of a number of specialized search engines that index the most relevant subsets of the Web and can offer task-specific tools. For example, if Li's system decides that a user searching for "pulled pork downtown" is more likely to be trying to make a dinner reservation than to find a butcher shop, it can kick the query over to a specialized engine that deals in restaurant searches, providing quick links to reviews and reservation systems. *—Jessica Mintz*

JOHN KEATLEY



BUILDING ROME IN A DAY
This digital model of the Colosseum was assembled by stitching together tourist photographs.

COMPUTING

Noah Snavely, 30

Synthesizing 3-D models from 2-D photographs

CORNELL UNIVERSITY

Every snap of a shutter—be it the subtle *click* of a DSLR or the artificial *ka-chak* of a smart phone—turns three-dimensional reality into a two-dimensional image. Noah Snavely is taking those images and using them to create 3-D digital models of structures ranging from individual houses to entire cities.

In 2006, as part of his PhD studies at the University of Washington, Snavely created a system that could assemble such models using an unstructured assortment of images from different cameras and viewpoints. "If we can find matching points between views," he says, "we can reason about where each image was taken and what the 3-D shape of the scene is." In 2008 his work was commercialized as Microsoft's Photosynth service, which allows users to upload photo collections and view them in a 3-D reconstruction of the space where they were taken. Snavely has even used his technology to reconstruct the city of Rome from the wealth of amateur images available online.

Snavely, now an assistant professor at Cornell, is trying to assemble a "distributed camera" composed of all the individual cameras whose pictures are shared online. He hopes to use those photos to construct a street-level digital model of much of the globe. —*Kenrick Vezina*

COMMUNICATIONS

Bhaskar Krishnamachari, 33

Smarter wireless networks

UNIVERSITY OF SOUTHERN CALIFORNIA

BY CREATING smarter wireless networks that can handle mobile devices and interference more efficiently than today's Wi-Fi and cellular networks, Bhaskar Krishnamachari aims to ease the increasing digital congestion of the airwaves and open the door to new applications for wireless communications.

For example, Krishnamachari is working with General Motors on a vehicle-to-vehicle network that lets cars in motion swap information about traffic flow and road conditions. His design can reliably route data within a shifting network of cars and other vehicles across freeways and city streets without having to tax the congested cellular network. One key to his approach is that data is not directed to specific addresses, as is standard in many computer networks. Instead, packets of data are labeled with tags that describe things such as the packet's contents, the geographic area the information is relevant to, and the time when the data should be considered out of date. Data is passed along the fleeting connections as needed and soon discarded. "This is opening up additional, almost free, bandwidth," he says. —*Tom Simonite*

COMMUNICATIONS

Ajit Narayanan, 30

Affordable speech synthesizers

INVENTION LABS

SOME FOUR MILLION people in India suffer from cerebral palsy and other disabilities that make it difficult or impossible for them to speak. Giving them a voice is the job of Ajit Narayanan's low-cost tablet-based system, Avaz. Even someone with only limited movement control can use Avaz to construct phrases that are spoken out loud by an artificial voice.

Speech synthesizers have long been used in the West (perhaps most famously by Stephen Hawking), but they are prohibitively expensive to all but the richest in India. Narayanan's Invention Labs, based in Chennai, designed Avaz to be not only cheap but also capable of supporting multiple languages. "The average young person in India speaks and uses three different languages every day," Narayanan points out. By working directly with Asian hardware manufacturers, he has been able to bring the cost of an Avaz down to around $800, compared with $5,000 to $10,000 for a single-language device in the United States.

Just over 100 of the devices have been sold so far, mainly to specialist schools, and they are in use by around 500 children. "I've seen parents weep when Avaz allows them to talk with their [child] for the first time," says Narayanan. He is currently working with the Indian Institute of Science, Bangalore, to improve the quality of the speech synthesis, and he also plans to use mobile app stores to distribute a version of his software with about 90 percent of the full Avaz system's functionality. —*Tom Simonite*

NOAH SNAVELY; SUJITH SUJAN (NARAYANAN)

35

MATERIALS

Fengnian Xia, 34

Replacing silicon with graphene

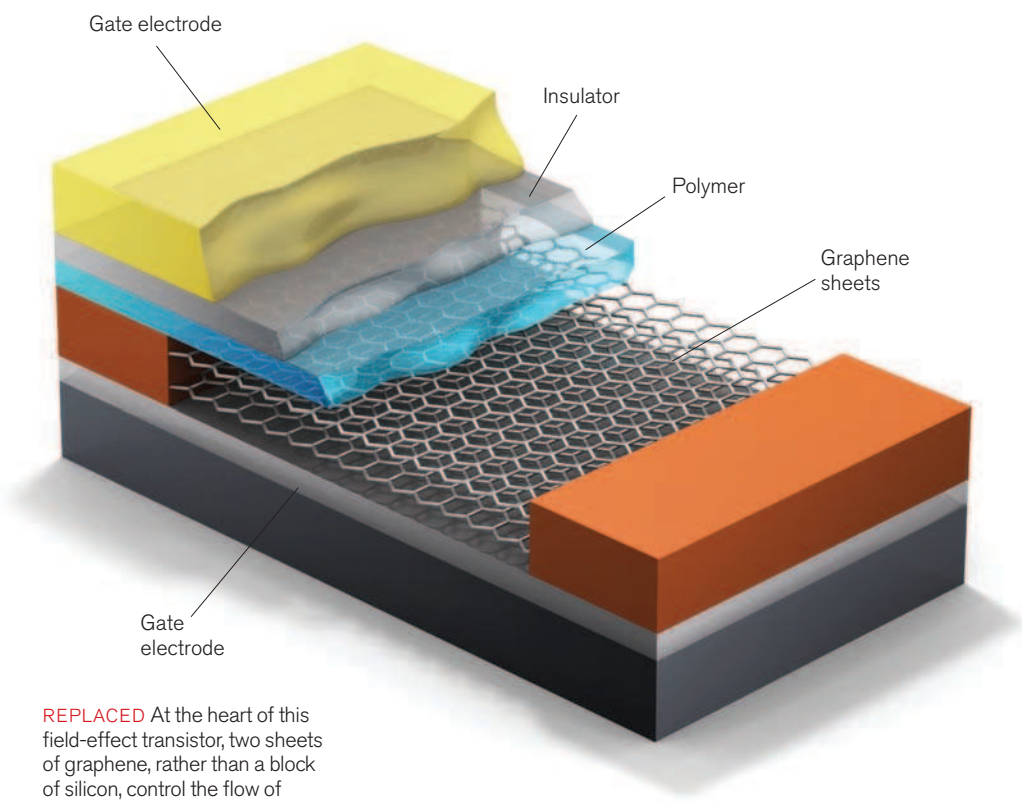
IBM

Fengnian Xia has found a way to build a graphene transistor that blocks electrons efficiently when it's off—a step in the direction of graphene-based electronics, which could lead to smaller, faster microprocessors.

Graphene is a promising material for transistors because it conducts electricity better than silicon does. Unfortunately, it's hard to stop the flow of electrons in graphene, and that's an essential function for any transistor. Xia's solution is based on a type of transistor in which an electric field is applied to two layers of graphene. In theory, this arrangement should stop the flow of electrons, but in practice, results were disappointing until Xia put a thin polymer layer on top of the graphene during fabrication: the polymer kept the electrical properties of the layers from being ruined as later layers were added to make other parts of the transistor.

Xia has also demonstrated that graphene can be used in ultrafast photodetectors for optical communications. The ultimate goal, he says, is an integrated system that uses graphene for both communications and computing. That would mean chips could use fiber optics instead of having their inputs and outputs bottlenecked by the relatively sluggish speeds of metal wires.

—Katherine Bourzac



REPLACED At the heart of this field-effect transistor, two sheets of graphene, rather than a block of silicon, control the flow of electricity through the device.

WEB

Chris Poole, 23

Designing online communities for anonymous collaboration

CANV.AS

4CHAN, founded in 2003 by Chris Poole (better known as "moot"), is one of the few corners of the Web that still celebrate faceless commentary and action. Poole's commitment to anonymity has helped 4Chan acquire more than 12 million active users; it boasts 600 million page views a month.

The 4Chan discussion boards have given rise to Internet memes that have helped shape popular culture, such as the continuing vogue for abruptly inserting Rick Astley's 1987 hit "Never Gonna Give You Up" into an online video (or live event). Less frivolously, the site was the birthplace of Anonymous, a collective of activist hackers who have targeted Scientology and companies that shunned WikiLeaks for publicizing government and corporate secrets.

When Poole built 4Chan, he did so with the concept of anonymity at its center, seeking to create a place where people have their mistakes forgotten

EMILY COOPER

JORDAN HOLLENDER

rather than being haunted by everything they've ever posted. There is no registration system, and users can post anonymously under whatever pseudonym they choose, even one associated with another user. There is no archive: content uploaded to the site by users disappears as new images and commentary are added.

Poole hopes to apply the lessons he has learned from 4Chan to a recent startup called Canv.as, which will allow users to share and edit images collaboratively using a built-in editor—anonymously, of course.

—Nick Bilton

BIOMEDICINE

Andrew Phillips, 34

Computer-assisted genetic engineering

MICROSOFT RESEARCH

SYNTHETIC BIOLOGY offers the prospect of engineering microbes to fight disease or produce biofuels, but designing the necessary DNA instructions is normally an arduous task. With software written by Andrew Phillips, who heads the Biological Computation Group at Microsoft Research in Cambridge, U.K., scientists can simply select the actions they want the microbe's proteins to perform and get back a corresponding DNA sequence.

The software bridges the gap between the kind of instructions biological designers would like to use—for example, "Convert protein A into protein B"—and the complicated reality inside cells, where countless reactions are taking place in parallel. It can generate multiple DNA sequences, coding for different ways a cell might produce the same desired result; users can then simulate the different possibilities. So far, the range of actions the software can handle is limited, but the Microsoft group has already used it to design live bacteria that change color when exposed to different molecules.

Phillips's software will reduce the number of time-consuming failures in real cells, says Douglas Densmore, a computer engineer and synthetic biologist at Boston University. It will enable designers to engineer biological systems that have "a greater probability of working consistently and correctly." *—Giselle Weiss*

ANNA KNOTT

MATERIALS

Alexandra Boltasseva, 33

Using semiconductors to steer light

PURDUE UNIVERSITY

PROBLEM: Metamaterials, a new class of artificial materials that can affect light in ways not possible in nature, open the door to things like real-life invisibility cloaks and computers that use photons instead of electrons. But current metamaterials absorb or scatter too much light to make such devices practical.

SOLUTION: Alexandra Boltasseva, a professor of electrical and computer engineering at Purdue University, is replacing the metals normally used in metamaterials with semiconductors, such as zinc oxide, that have been doped with aluminum or gallium. Doping the semiconductor makes it behave more like the metals used in metamaterials, but without the associated optical losses. Currently, these doped semiconductors are suitable for manipulating infrared light, and Boltasseva is working on developing formulations that will work with visible light. Another advantage of these materials is that their properties can be altered by applying an electric field, which would make them suitable for applications such as communications and computing.

"We are talking about a whole new generation of devices that are based on new principles of manipulating light," she says. *—David Talbot*

GABRIELA HASBUN

COMPUTING

Piya Sorcar, 33

Software that can be localized to teach taboo topics

TEACHAIDS

Despite considerable educational efforts by experts and organizations alike, public awareness in India about the growing HIV epidemic has remained low. So Piya Sorcar, founder and CEO of TeachAIDS, has developed interactive software to educate children about HIV in a way that's sensitive to the country's cultural mores.

When Sorcar traveled to India in 2005, she found that even children and young adults who received training on HIV didn't learn much: cultural taboos prevented educators from speaking frankly about how the virus is transmitted. As she designed her software, she took pains to ensure that it didn't run afoul of those taboos. She analyzed cultural responses to every image used. She recorded narration with correct local accents, created gender-specific versions of each program, enlisted local celebrities for voice acting, and tested to see how much information children retained, even long after the lessons were over.

The cultural sensitivity has paid off: Sorcar's software has been approved and distributed by states in India where other sex education is banned. The software has been designed to be modular, so that it's easy to swap in locally appropriate elements. The country of Botswana has approved it for every school in the nation, and Sorcar hopes to distribute it to countries around the world within five years.

—Erica Naone

35

COMPUTING

Gert Lanckriet, 34

Teaching computers to classify music

UNIVERSITY OF CALIFORNIA, SAN DIEGO

IS LADY GAGA'S "Born This Way" a happy song? Is "Bohemian Rhapsody" sad? Gert Lanckriet wants computers to be able to tell. Then people could search for tunes that match a particular mood or instrumental style, and an online store could make better recommendations.

Lanckriet, an associate professor in the Department of Electrical and Computer Engineering at the University of California, San Diego, started by having his computers analyze a collection of 500 popular songs that human judges had categorized in six ways—by genre and tempo, for example. When fed a new piece of music not in the database, the computer uses that training to infer how a human would characterize it. Lanckriet continues to train the system through a Facebook game called Herd It, launched in 2009. Players listen to snippets of music and win points if they agree with the majority of their fellow users; the results are fed into Lanckriet's software.

After the software gets some more fine-tuning, Lanckriet plans to let it crawl the Web like a search engine, automatically classifying the huge amount of music available online. He's also exploring how to use the sensors in smart phones to cue up exactly the sort of music someone is in the mood for. If the phone's accelerometer detects that the user is exercising, it could choose something energetic, while sitting in a quiet room at night might lead it to choose something mellower.

—Kenrick Vezina

GREGG SEGAL

BIOMEDICINE

Fan Yang, 31

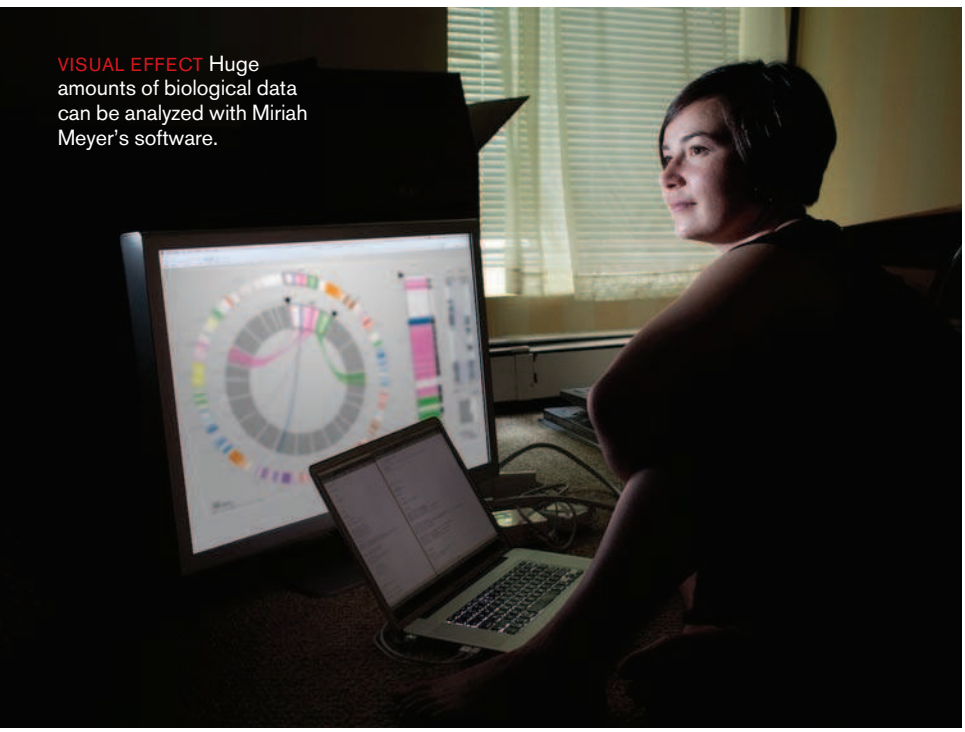
Reprogramming stem cells to repair blood vessels

STANFORD UNIVERSITY

INJURY AND DISEASE can damage blood vessels. But Fan Yang, a Stanford professor of bioengineering and orthopedic surgery, has developed a way to persuade the body to repair them.

In her technique, stem cells are reprogrammed in the lab to produce a protein that stimulates the growth of blood vessels. Then the cells are injected into diseased areas of the body. Previous attempts to use this approach ran into problems because researchers relied on viruses to transport the protein-producing genetic instructions into the stem cells. Instead, Yang has made a biodegradable polymer that binds weakly to strands of DNA, clumping together to form nanoparticles that penetrate the stem cells and release the desired instructions. Because these polymers degrade naturally after use, the treatment is potentially safer than viral methods.

Yang believes that eventually the technology could be used to treat the damage caused by heart attacks, strokes, and diabetic ulcers. She's now collaborating with Stanford surgeons and further improving the nanoparticles, but she estimates that it will be five to 10 years before the therapies move "from bench to bedside." —*Kristina Bjoran*



VISUAL EFFECT Huge amounts of biological data can be analyzed with Miriah Meyer's software.

BIOMEDICINE

Miriah Meyer, 34

Extending data visualization to biology

UNIVERSITY OF UTAH

Biological research is exploding with genomic, molecular, and chemical data. But analyzing all that information has been difficult and slow, in part because biologists haven't had good ways to visualize the data—to see it represented graphically on screen so as to help them spot trends and make comparisons. University of Utah computer science professor Miriah Meyer is addressing that problem by developing programs that make it easier for scientists to explore the data they're generating. For instance, Meyer has built an interactive program that lets researchers compare different organisms' genomes, which is useful for understanding evolutionary trends. Scientists also benefit when something doesn't look right on the screen, because that can reveal a mistake in their data that might otherwise take months to uncover.

Although custom visualization tools are used in many other fields, such as economics, computer science, and engineering, they have been surprisingly slow to spread to biology, says Angela DePace, a biologist at Harvard who has collaborated with Meyer. "More often than not, biologists make do with out-of-the-box solutions that are difficult to tailor to their needs," she says. That tailoring is just what Meyer tries to do. She spends months working with scientists to understand the specifics of their projects—and how a graphical representation can help.

—Emily Singer

COMMUNICATIONS

Umar Saif, 32

Improving connectivity in poor nations

LAHORE UNIVERSITY OF MANAGEMENT SCIENCES

IN PAKISTAN, the bandwidth of an average landline is about 32 kilobits per second (as of 2011, the average broadband speed in the United States was 5.3 megabits per second). It can take more than 20 minutes to download a five-megabyte file—assuming the connection doesn't drop during that time, as it frequently does. To help relieve the frustration, Umar Saif developed BitMate. The software lets different users in the same area pool the bandwidth of their connections to reduce download times, typically by half. Released in February, the software has already been downloaded more than 30,000 times by people in 173 countries.

Saif previously created a service that linked mobile phones into groups so that mass SMS messages could be sent. Since its launch in 2008, it has been used to send nearly four billion texts to about 2.4 million users in Pakistan, and the service, now called SMSall, has been used to coördinate protests, find missing persons, and organize blood drives. This summer Saif began expanding SMSall beyond Pakistan to Nigeria, Iraq, Bangladesh, and the Philippines. "SMS is the door to the world for many people," he says. *—Kristina Bjoran*

MARK OSTOW

WARRICK PAGE/GETTY IMAGES

POWER DRILL High-energy laser light is sent through a fiber-optic cable to this drill head, allowing it to bore through solid rock (inset).

ENERGY

Joel Moxley, 31

Drilling with lasers

FORO ENERGY

Vast quantities of oil and natural gas are trapped under rock that's too hard to drill though economically with existing technology. Joel Moxley's startup, Foro Energy, wants to use high-powered lasers to carve through rock that stymies conventional drill bits, making these resources cheaper to extract.

Lasers powerful enough to blast through rock are already available, and recent advances have made them more transportable. But they are too big and fragile to be sent down the borehole, and conventional fiber optics can't transport high-energy laser beams over long distances. That was the problem Moxley aimed to solve when he founded Foro, in 2009. As CEO, he gathered some of the world's best experts on high-powered lasers, established joint development partnerships with major energy companies, and raised over $20 million in venture capital and government grants. The result: Foro has designed a system that can direct laser beams along more than 3,500 meters of fiber-optic cable while retaining enough power to cut through hard rock two to four times as fast as conventional bits, lowering drilling costs by two-thirds. The technology caught the attention of the Department of Energy's Advanced Research Projects Agency for Energy, which gave Foro one of the largest awards it has granted. "Laser-based drilling was considered crazy even five years ago," says David Danielson, a program manager at ARPA-E. Now, Moxley says, commercial drilling could begin in two to three years. *—Kevin Bullis*

WEB

Jesse Robbins, 33

Fault-tolerant online infrastructure

OPSCODE

IN 2001, Jesse Robbins applied for two jobs: one as a Seattle bus driver and another as a backup systems engineer at Amazon.com. Amazon called first, and in the decade that followed, Robbins transformed the way Web companies design and manage complex networks of servers and software.

A former volunteer firefighter, Robbins brought an emergency responder's mind-set to his work. He taught Amazon that with data centers distributed around the world, a massive shopping site, and intricate fulfillment operations, some unpredictable and spectacular failures were inevitable. Rather than try to defy that inevitability, Robbins says, he made it safe for Amazon to fail, building fault tolerance into its architecture. Then he tested the Web operations teams with live drills, knocking entire data centers offline. Customers didn't notice a thing.

After leaving Amazon in 2006, Robbins began blogging about his techniques. In 2007, he founded Velocity, now an annual conference, where fierce competitors such as Microsoft and Google share information

COURTESY OF FORO ENERGY

JOHN KEATLEY

about handling infrastructure problems.

In 2008, Robbins cofounded Opscode. Its main product, Chef, is an open-source programming language that automates management of cloud-based infrastructure. For example, one client used Chef to help scientists bring up and configure in 45 minutes a 10,000-processor supercomputing cluster on Amazon's pay-as-you-go cloud, solve some difficult problems related to protein binding in eight hours, and then close out the operation, for a small fraction of what it would cost to build or buy time on a supercomputer. *—Jessica Mintz*

COMPUTING

Brian Gerkey, 34

A common language for robots

WILLOW GARAGE

PROBLEM: People who want to program robots have had to either write software from scratch or purchase proprietary software that is hard to modify. SOLUTION: Brian Gerkey has developed open-source platforms, called Player and ROS, that standardize the basic software used to control a robot. Both have been adopted by thousands of companies, universities, and governments around the world.

Gerkey believes the software will allow entrepreneurs to create new commercial applications for robots even if they don't have extensive robotics expertise. The goal is to help "people who have ideas for what robots can do in the marketplace," he says. Much of the development of ROS is happening at Willow Garage, a robot technology incubator, where Gerkey is the director of open-source development. The first full version of ROS, which can handle more complex robots than Player, was released in 2010. By encouraging the adoption of ROS, Willow Garage is also increasing the market for its own robots, which it hopes will become the de facto hardware standard for would-be robot entrepreneurs. *—Kristina Grifantini*

DANA SMITH

BIOMEDICINE

Ben Rubin, 28

Letting consumers analyze their sleep

ZEO

IN COLLEGE at Brown University, Ben Rubin had an odd nighttime ritual. He would hook himself up to an old polysomnography machine, a refrigerator-size device that clinics use to diagnose sleep disorders. He wanted to create a wearable alarm clock that would measure brain activity and wake the user in an optimal phase of light sleep. Before he graduated, Rubin cofounded a company called Zeo, and in 2009 it began selling the first consumer device that detects the user's phase of sleep.

The $200 device consists of a fabric headband with embedded sensors that pick up electrical signals from the brain and send them throughout the night to a base-station clock next to the bed. In the morning, the clock displays the amount of time spent in light, deep, and REM sleep; the number of awakenings during the night; and a score that incorporates all these values into a single number. Accompanying software provides suggestions to improve sleep quality, and users can further explore their sleep data on Zeo's website.

Zeo's sleep monitor is one of a growing number of consumer tools designed to monitor health and fitness, and Rubin has become an advocate for the idea that people can take more control of their health. "These tools give people the ability to do that," he says. "People don't value sleep as they should." *—Emily Singer*

TOBY BURDITT

COMPUTING

Jeff Hammerbacher, 28

Managing huge data sets

CLOUDERA

In 2006, as Facebook was starting to accumulate information about its users faster than the data could be analyzed and stored, Jeff Hammerbacher was brought in to deal with the problem. A former Wall Street number cruncher, he soon developed techniques for handling and mining unprecedented amounts of data.

Realizing that the company needed entirely new technology to handle the information overload, Hammerbacher threw Facebook's muscle behind a relatively new open-source database project called Hadoop, which allows nearly real-time processing of data in quantities that had previously been impossible. Hadoop enabled Hammerbacher to create the suite of analytics that underpins Facebook's targeted advertising system—the key to the company's profitability.

Though much of the technology he constructed is still in use at Facebook, Hammerbacher left in 2008 to found a company called Cloudera, where he is now chief scientist. Cloudera is devoted to developing Hadoop and related open-source technologies. Hammerbacher points out that industries including oil and gas, retail, and life sciences are all dealing with increasing amounts of data. They could use such technology to extract valuable insights from the deluge. *—Erica Naone*

ENERGY

Yu-Guo Guo, *33*

Creating a cheap, safe material for electric-vehicle batteries

WUHE

Advanced nanostructures invented by Yu-Guo Guo could lead to electric-car batteries that deliver more power at 10 percent less cost. That's significant because battery packs account for a great deal of the cost of electric cars such as the Nissan Leaf. A car with a big battery pack is too expensive for most people, but models that keep costs down with a smaller battery pack can't go very far on a charge.

For Guo, a professor of chemistry at the Chinese Academy of Sciences in Beijing, the crucial innovation was a better way to use lithium iron phosphate. Automakers like the material because its stable chemistry makes it safe for use in large electric-vehicle battery packs. But ordinarily, it is not conductive enough to be useful. Some manufacturers have tried milling the phosphate into an extremely fine powder that's more conductive but difficult to work with. Guo's solution was to incorporate phosphate nanoparticles into larger particles made of porous carbon. These particles retain the high conductivity of the powder, but they are easier to pack closely and less likely to become airborne.

Late last year Guo founded a company, Wuhe, that will produce enough material for 30 million lithium-ion battery cells this year—enough for roughly 5,000 car battery packs. The cells are currently being sold for use in electric bicycles and being tested for use in electric cars. *—Kevin Bullis*

MATERIALS

Solomon Assefa, *32*

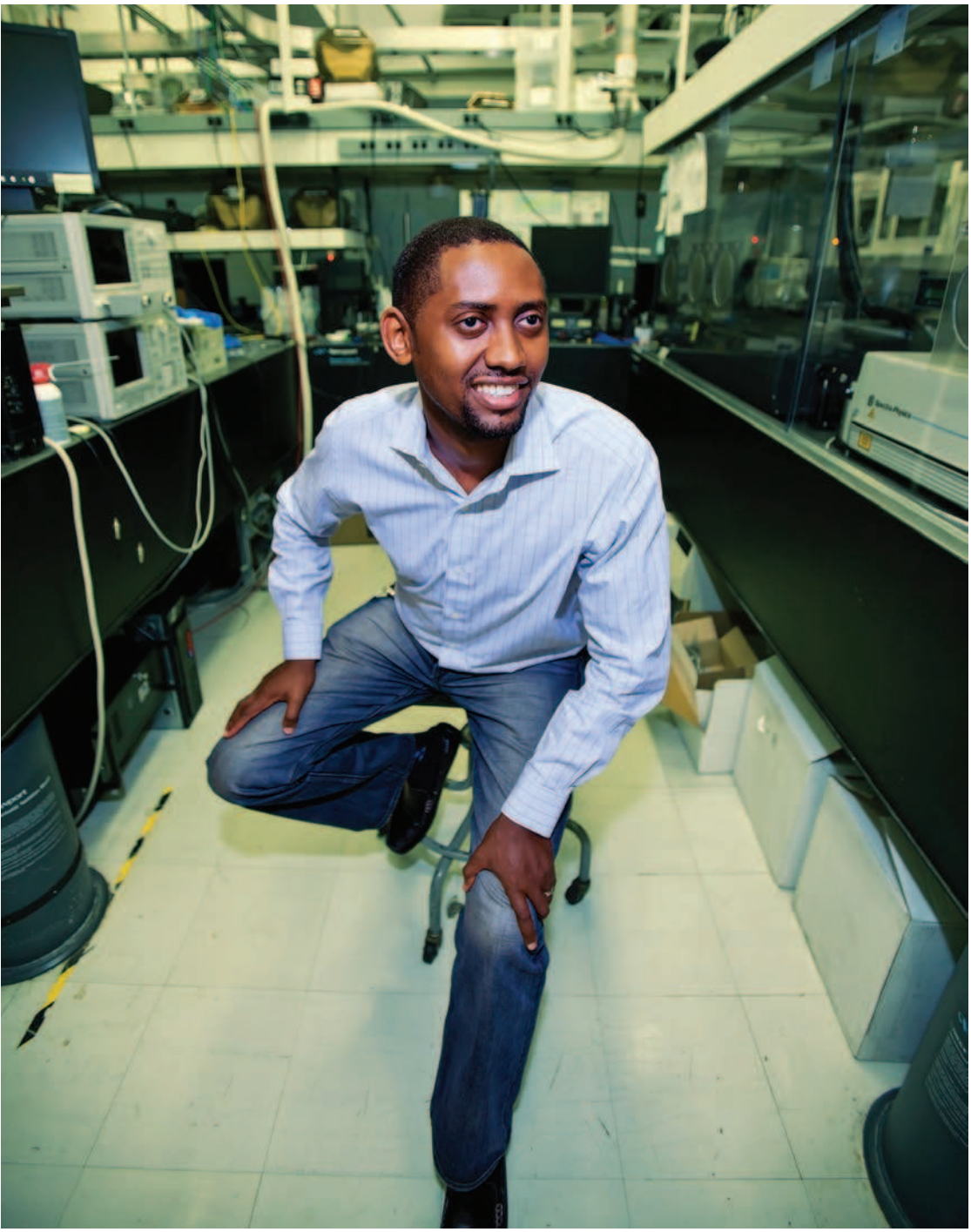
Replacing wires with light in chips

IBM

CHIPS THAT communicate with pulses of light instead of electrical signals could lead to computers that are more power-efficient than today's best machines and up to 1,000 times as fast. IBM researcher Solomon Assefa has brought this prospect a critical step closer.

Assefa has developed a new way to make a photodetector, a very sensitive device that amplifies optical signals and converts them into electrical signals that can be shuttled around in a microprocessor. Ordinarily, photodetectors are made using a process called chemical vapor deposition. But sticking with this process for chip-to-chip connections would make microprocessor manufacturing prohibitively expensive. Instead, Assefa seeds germanium onto a silicon wafer, and then melts it to achieve the regular crystal structure that makes for a good photodetector material. He has also determined when in the chip manufacturing process the photodetector should be added in order to get the best performance possible without degrading the surrounding electronics.

LAURA BARISONZI/GETTY IMAGES



STEVE MOORS

Assefa can demonstrate the performance of his photodetector in the lab. But before a chip incorporating his creation can be commercialized, he will have to figure out how all the rest of its elements can be integrated efficiently. Making today's integrated circuits requires hundreds of steps and dozens of lithographic masks, the stencils used to pattern features on chips. "We don't want to change any of these processes or it really increases the costs," he says. *—Katherine Bourzac*

COMPUTING

June Andronick, 32

Software that can't crash

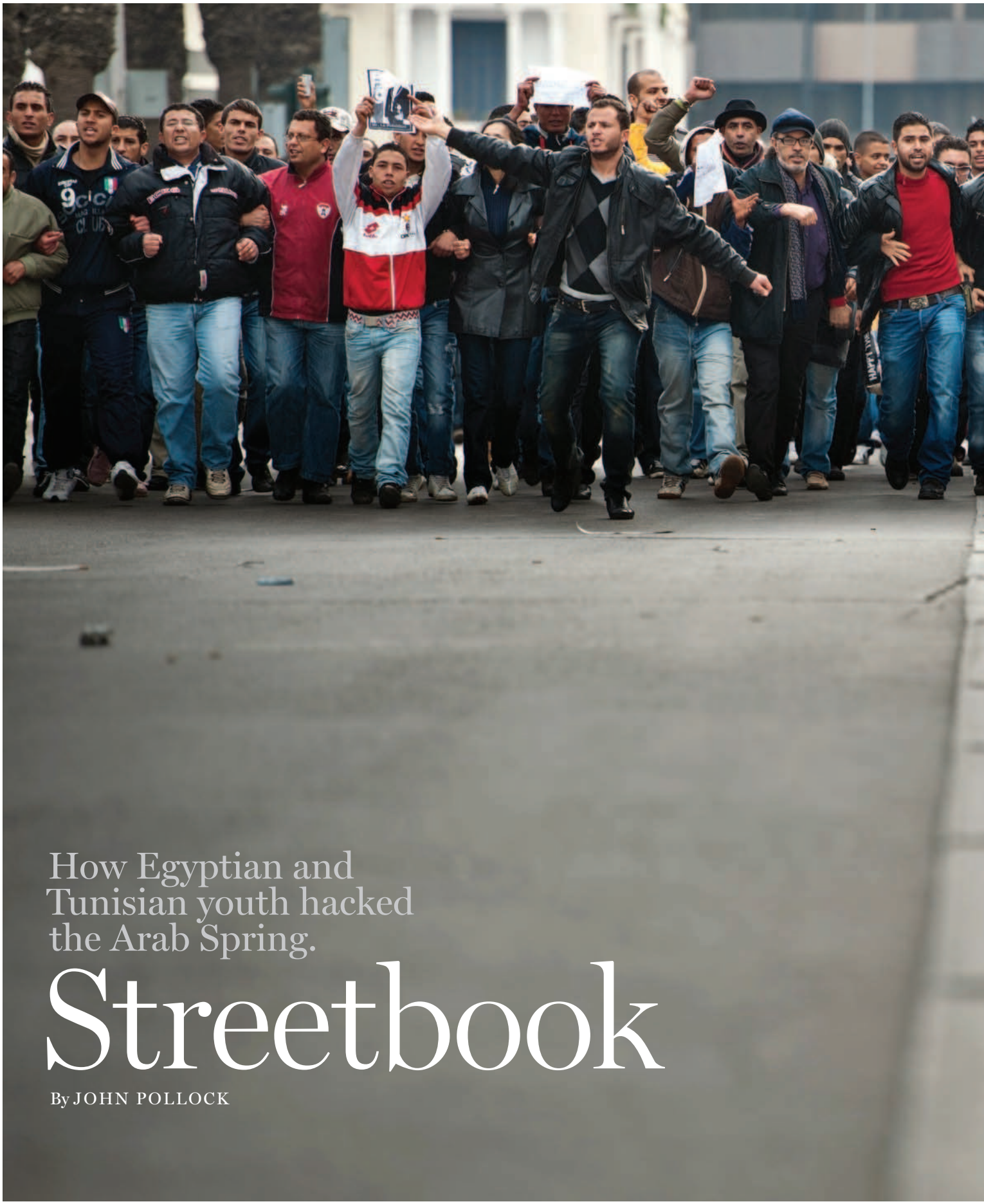
NICTA

PROBLEM: To test the reliability of software that controls embedded chips in medical devices and vehicles, computer scientists have relied on trial-and-error methods that can miss bugs. SOLUTION: By using mathematical analysis to prove that a piece of software is reliable, June Andronick can take into account all possible inputs to the software, and all the possible ways the software could process those inputs.

Working at Australia's national IT research center (NICTA), Andronick and colleagues in Gerwin Klein's lab were able to use this analytical technique to write a small operating system that will always behave exactly as intended, never crashing (barring incorrect assumptions about the hardware).

Because the OS acts as the gatekeeper to the hardware, it can block instructions that would cause a crash—say, instructions coming from the application software that makes decisions about how an engine should be throttled. Some computer scientists predict that mathematically verifying the reliability of critical software components will become the norm in certain systems.

The technology could also help protect against cyber-attacks, Andronick says. The operating system could block unauthorized actions that are issued by software that has been hacked through some point of vulnerability, such as a Web browser. "The attack on the untrusted part can't keep the trusted part from functioning correctly," she says. *—William M. Bulkeley*



How Egyptian and Tunisian youth hacked the Arab Spring.

Streetbook

By JOHN POLLOCK

MARTIN BUREAU/AFP/GETTY IMAGES

OUTCRY Citizens demonstrate in Tunis, Tunisia, on January 20, 2011. Similar protests had already led President Ben Ali to flee the country; now the protesters were angry that members of his party remained in the transitional government.

The street revolutions that overthrew the presidents of Egypt and Tunisia in January and February had no Lenin or Trotsky; but two secretive Tunisians known as "Foetus" and "Waterman," and their organization, Takriz, performed a remarkable and largely unknown role. Many groups helped remove Tunisia's President Zine El Abidine Ben Ali after 23 years in power—students, unionists, lawyers, teachers, human rights activists, and online dissidents—and Takriz has links with all of these. But its main audience is alienated street youth: the lifeblood, often spilled, of the rebellion in North Africa. That youth rebellion has since spread far beyond Tunisia and Egypt to enflame the entire region. The Arab Spring or Arab Awakening will smolder for years to come. And the combination of online and offline strategies and tactics that Takriz and others helped develop will be scrutinized for decades.

Takriz began as a tiny self-described "cyber think tank" in 1998. Although it has grown into a loose network of several thousand, the Takrizards, or Taks, rarely coöperate with journalists and carefully guard their anonymity. "Takriz" itself is an elusive word. It's a street-slang profanity that expresses a feeling of frustrated anger: "breaking my balls" or "bollocks to that." But what *Le Monde* called the group's "irreducible insolence" belies a professional focus. Foetus, a technology consultant with an MBA and half a dozen languages, is a slight figure with a booming voice. He plays off his childhood friend Waterman, a big but more retiring man with a gift for writing. Takriz quickly got under the skin of the regime and has stayed there, even after the revolution. Hunted and exiled for years, many core Taks can still enter their country only with extreme caution, often undercover.

For Takriz, Ben Ali's removal has changed little: the group believes that Tunisia's interim government is cut from the same corrupted cloth as its predecessor. The situation is similar elsewhere in the region. Activists in Egypt are wary of the repressive Supreme Council of the Armed Forces that replaced Egypt's president, Hosni Mubarak. Meanwhile, founding members of Morocco's February 20 movement, who seek constitutional reform rather than revolution, perceive changes recently proposed by King Mohammed as mere political theater. The elderly regimes of the Middle East and North Africa are unwilling to leave the stage, yet unable to satisfy the political and economic demands of a demographic youth bulge: around two thirds of the region's population is under 30, and youth unemployment stands at 24 percent. Inevitably, the rapidly changing landscape of media technology, from satellite TV and cell phones to YouTube and Facebook, is adding a new dynamic to the calculus of power between the generations.

THE TACTICIAN "Foetus" guards his anonymity. The chief technology officer of the Tunisian organization Takriz, which excited the alienated youth of the streets to overthrow the government of President Ben Ali, took this photograph with his mobile phone and sent it to the author.

GOING UNDERGROUND

Takriz started with modest aims, including freedom of speech and affordable Internet access. Waterman recalls that the Internet was the only viable option for organizers in 1998, because other media were controlled by Ben Ali. Foetus, Takriz's chief technology officer, a skilled hacker who started hacking because he couldn't afford Tunisia's then-exorbitant phone and Internet costs, saw another advantage online: safety. Takriz meetings "in real life" meant "spies and police and all these Stasi," he says, using the term for East Germany's secret police. "Online we could be anonymous."

Anonymous, perhaps, but they soon caught the regime's attention. The government blocked Takriz's website within Tunisia in August 2000, around the same time it blocked several others, including those of Amnesty International and Reporters Without Borders. Other Tunisian sites sprang up to take its place. A core

Editor's note: Foetus and Waterman asked to preserve their anonymity as a condition for speaking to Technology Review. *Our rule is that sources should remain anonymous if their safety or the safety of their families demands it. In such cases, we ask the writer of a story to tell its editor the sources' identities. Here, unusually, although the writer spent many days with Foetus and spoke to Waterman over Skype, he never learned their real names. But we interviewed people who know the two revolutionaries. We are confident they are persistent personalities, not* noms de guerre *assumed by different people at different times, and that they did what they say they did.*

Tak called SuX launched the first Arab-African social network, SuXydelik. Zouhair Yahyaoui, an older Takrizard then in his 30s, known online as "Ettounsi" ("The Tunisian"), started TuneZine, a humorous political webzine and forum that inspired many, not least with jokes such as this:

> TuneZine is launching a competition for jokes, reserved for young people, about Ben Ali and his party.
> First prize: 13 years in prison.
> Second prize: 20 years in prison.
> Third prize: 26 years in prison.

TuneZine made Ettounsi famous in Tunisia; it also led to his arrest and torture. He was sent to one of the worst prisons in the country, according to his brother Chokri, with 120 people in one room—"just one bathroom and hardly any water." His sister Layla recalls that when he became sick and asked to see a doctor, "they beat him." He went on several hunger strikes.

In 2003 the PEN American Center gave Ettounsi its Freedom to Write Award, and Reporters Without Borders awarded him its first Cyber-Freedom Prize. That year he was released, but in terrible shape; he could barely walk. As Ben Ali prepared to host the 2005 World Summit on the Information Society (WSIS), Ettounsi went to Switzerland for the pre-summit, remarking, "Maybe when I go back to Tunis I'll be arrested again. It's a risk, but I take it." A few months before WSIS, he died of a heart attack, aged 37. It was a death hastened, in many eyes, by his treatment in prison. At the summit, Ben Ali imposed a local curfew. Activists and journalists were attacked, websites blocked, speeches and documents censored, and when a squad of plainclothes police turned up at a Global Voices meeting on "expression under repression," the irony almost caused a diplomatic incident.

Even earlier, Takriz members had faced death threats and arrests. They call the early 2000s the "manhunt years," when many members suspended their political activities as they forged new lives in exile. But the persecution of Ettounsi radicalized other Tunisians, like Riadh "Astrubal" Guerfali, a law professor in France. He made a parody of the Apple Macintosh "1984" video, with Ben Ali as Big Brother, and cofounded a collective blog, Nawaat, with a Tunisian exile, Sami Ben Gharbia. Guerfali and Gharbia found innovative ways to use technology: scouring plane-spotter sites for a video exposé of the reviled first lady, Leila, using the presidential jet to go shopping; "geo-bombing" the presidential palace by adding videos of human rights testimony that appear in the YouTube layer of Google Earth and Google Maps; and charting Tunisia's prisons.

Another innovation is Takriz's strong relationship with soccer fans. The mosque and the soccer pitch have been the only release valves for anger and frustration among the young under autocratic Middle Eastern rule, says James M. Dorsey, senior fellow at the Nanyang Technological University's S. Rajaratnam School of International Studies, who writes a blog called The Turbulent World of Middle East Soccer. "Soccer gets little attention," he says, "because soccer fans don't bomb World Trade Centers." They fight local battles instead, often against the police.

The inspiration for turning that spirit to political ends came after several Taks, including Foetus and SuX, were at a 1999 Tunisian cup match that erupted in violence. Scores were injured and several died. Ben Ali was appalled, but exiled Taks soon saw an advantage in working with Ultras, as the most extreme fans of soccer clubs are known. Over several seasons, SuX, who had a particular rapport with the fans on the terraces, developed a Web forum for Ultras from different teams, hosted by Takriz. A distinctive North African style of Ultra—one with more political character—spread quickly among Tunisia's soccer-mad youth and then to fans in Egypt, Algeria, Libya, and Morocco. When the revolution began, the Ultras would come out to play a very different game. They were transformed into a quick-reaction force of bloody-minded rioters.

"We didn't think about Facebook in the beginning because [to us] it was very new," says an Egyptian organizer. Instead they relied on leaflets, blogs, and Internet forums. When they did set up a Facebook page, they were amazed to see 3,000 new fans a day.

REHEARSALS

In 2008, protests focusing on corruption and working conditions broke out in Tunisia's mining region, near the town of Gafsa. Six months of sporadic demonstrations peaked when security forces opened fire, killing one and injuring 26. There were hundreds of arrests. The unrest remained local, though, in large part because security forces cut the area off. Foetus admits it was "hard to build on these events" because "the technology wasn't in place": few Tunisians had camera phones or Facebook accounts. But Takriz sent members south, hoping to build networks on the ground by strengthening relationships with local union and youth activists.

Egypt, too, saw industrial protests in 2008, in this case in the city of Mahalla in the Nile Delta. Textile workers there planned a

strike on April 6. Ahmed Maher, a 27-year-old civil engineer and activist, heard about it and decided to help by organizing further demonstrations in Cairo and a national shopping boycott.

"We didn't think about Facebook in the beginning because [to us] it was very new," says Maher. Instead the Egyptian organizers relied on leaflets, blogs, and Internet forums. When they did set up a Facebook page, they were amazed to see 3,000 new fans a day. At that stage, Maher saw little hope of immediately ousting Mubarak. "The main target was to inspire and encourage people to say no," he says. "It was like training. The day was a rehearsal."

A month after the April 6 protests, Maher was arrested, beaten for hours, and threatened with rape. On his release he called a press conference, where he spontaneously announced that he was starting the "April 6 movement." He set out to find a cadre of independent-minded young people to join him. April 6 would become the core of the secular youth movement of the Egyptian uprising—a counterpart to the youth movement of the Muslim Brotherhood.

The first thing the April 6 leaders did was study. They started with the Academy of Change, an Arabic online group promoting nonviolent civil disobedience. Its inspiration was Optor, a youth movement cofounded by a Serbian revolutionary, Ivan Marovic, which helped overthrow Yugoslavia's Slobodan Miloševic in 2000 by means of a "Bulldozer Revolution" that was remarkably peaceful: only two people died. Marovic later cofounded the Center for Applied Non-Violent Action and Strategies (Canvas), which has since trained activists from more than 50 countries. In the summer of 2009, April 6 sent an activist named Mohammed Adel to train with Canvas in Serbia. He returned with a book about peaceful tactics and a computer game called A Force More Powerful, which lets people play with scenarios for regime change. Taking advantage of the game's Creative Commons license, April 6 members wrote an Egyptian version. "We used it to help train our activists," says Maher.

In Tunisia, meanwhile, Ben Ali's online censorship had been growing increasingly draconian. (In 2009 Freedom House would rank Tunisia below China and Iran on measures of Internet freedom.) Dailymotion and YouTube were blocked in 2007. A technique called deep packet inspection (which is much what it sounds like) was used to stop e-mail deliveries, strip read messages from in-boxes, and prevent attachments to Yahoo mail. Reports about Gafsa on Facebook, which then included just 28,000 of some two million Tunisians online, led the regime to block Facebook itself for two weeks. By October 2009, with national elections approaching, over 800,000 were on the social-networking service. (As Ben Ali fled more than a year later, the number would reach 1.97 million—over half of Tunisians online, and almost a fifth of the total population.)

For Takriz, Ben Ali's 2009 reëlection was the last straw. Foetus could imagine another decade of "Ben Ali and his mafia" looming, but he believed that people were too scared to act. "So we turned up the heat in the stadiums and started boiling the Internet," he says. "We decided to fuck everybody." On Facebook the activists called out the opposition for its timidity. "We had to 'electroshock' them to get people to do that last step," Waterman says. "Then we built momentum, momentum, momentum."

This was just one of various tactics, from serious political analysis and leaked documents to scabrous polemic, that Takriz deploys to reach multiple audiences. Its leaders use street culture, slang, and obscenities to fire up street youth. As Takriz got harder and angrier, it lost goodwill with some bourgeois Tunisians. It was not just the bad language that troubled: to some, they seemed to be hooligans. August 11, 2010, marked 10 years since the regime had begun censoring the group's website. Takriz commemorated the occasion by posting a video of a Tak urinating on Ben Ali's photo. The youth minister was incensed, calling Takriz "black-hearted monsters hidden in dirty places and online." The group had spoiled a pet initiative Ben Ali proposed to the UN: the 2010 International Year of Youth: Dialogue and Mutual Understanding, which began the next day, on August 12.

Takriz also tweaked Ben Ali's paranoia about a coup d'etat. It created a fake Twitter account and a website, KamelMorjane.com, that featured pictures of Morjane, Tunisia's foreign minister, meeting world leaders. Official photos of such meetings would usually include Ben Ali or at least his portrait in the background. Takriz chose photos without Ben Ali, says Foetus, "to mess with his head." It was psychological warfare on the inner circle.

JOHN POLLOCK

THE WRITING ON THE WALL Graffiti seen in Cairo this spring (opposite page) cites a movie that is popular among Ultra soccer fans and political activists: *V for Vendetta*. Above, a message captured on a Tunis street in January translates to "Thanks to the People! Thanks Facebook!"

CAPUCINE BAILLY/REDUX

TWO ICONS

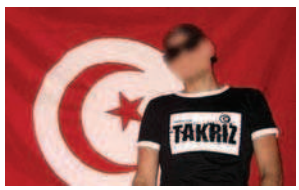
The summer of 2010 also marked the beginning of Egypt's revolution. On June 6, 2010, a young computer programmer named Khaled Said was at a cybercafé in Alexandria when he was dragged out by two plainclothes policemen and beaten to death in the street. The police claimed he was resisting arrest. His family says that he had compromising videos showing the police dealing drugs, and that the authorities feared he would use a tactic that had become popular in Egypt: uploads on YouTube and Facebook.

Said became a revolutionary icon when ghastly post-mortem photos, taken on his brother Ahmed's cell phone, were posted to Facebook. We Are All Khaled Said emerged as an enormously influential Facebook group; it now has almost 1.5 million members. Hassan Mostafa, a burly local activist, first saw the photos on his cell phone and immediately used his own Facebook page to call for a protest outside the police station. More than a dozen protesters were arrested and severely beaten. Mostafa would later be jailed for six months, after several more protests including a mock trial of the Mubarak regime performed outside the Said family home. "It was a fiction that has become a reality," he says. The April 6 founder Ahmed Maher calls Mostafa "a movement in himself." He adds, "He is a man worth a complete movement!"

The revolutions cooked over a long, hot summer. The global financial crisis bit, food prices rose, and a baking August Ramadan brought a month of days without food and drink. Neither Tunisia nor Egypt had much to celebrate.

Days after the Egyptian parliamentary elections, described as the most fraudulent ever by some human rights groups, Tunisia's revolution began as it would end, in flames. On December 17, Mohamed Bouazizi, a poor vegetable seller, set himself on fire in Sidi Bouzid in protest of a series of humiliations suffered at the hands of petty officialdom. Peaceful protests that broke out in response met with heavy-handed reaction, as reports online made clear, but the country's tamed media kept quiet. Bouazizi's death galvanized hitherto isolated pockets of resistance. "People realized it was now or never," says Haythem El Mekki, who hosts a TV show about Internet society in Tunisia. They had to "go to the streets and scream and shout." A Tak in Sidi Bouzid contacted the Takriz Facebook page admin about the first protests. He was

KEY MOMENTS IN THE ARAB SPRING



1998
The electronic mailing list Takriz is created, with an initial focus on issues like freedom of speech and affordable Internet access in Tunisia. It will eventually be censored by the government.

JANUARY 2008
Six months of protests begin near Gafsa, Tunisia, over corruption and bad working conditions.

APRIL 6, 2008
Protests begin in an Egyptian industrial city, El-Mahalla el-Kobra.

OCTOBER 25, 2009
Tunisia's President Ben Ali is reëlected, with a suspiciously high 89 percent of the vote.

JUNE 6, 2010
A young computer programmer, Khaled Said, is beaten to death by police after being arrested at a cybercafé. He will become Egypt's revolutionary icon after ghastly post-mortem photos taken on his brother's phone are posted to Facebook.

NOVEMBER 28, 2010
Wikileaks releases a trove of U.S. diplomatic documents. Tunisian dissidents set up a website to publicize the cables that document repression by their government.

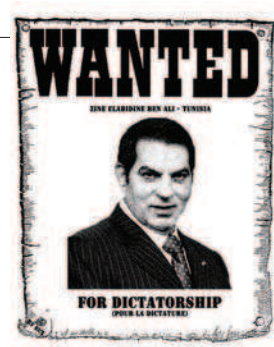
DECEMBER 17, 2010
Mohamed Bouazizi, a poor vegetable seller, sets himself on fire, triggering the Tunisian revolution.

DECEMBER 31, 2010
Lawyers assemble to protest in cities throughout Tunisia. They are attacked and beaten by security forces.

JANUARY 2, 2011
The hacking group Anonymous announces Operation Tunisia and begins targeting government websites with denial-of-service attacks.

JANUARY 6, 2011
Two weeks after attempting to hack into dissidents' accounts on social networks, Tunisian authorities arrest several prominent activists.

JANUARY 8, 2011
The regime intensifies its crackdown; over the next five days, dozens of people are killed in protests.



JANUARY 13, 2011
Ben Ali addresses the nation, expressing "very, very deep and massive regret" about the deaths. He offers to stand down in 2014.

JANUARY 14, 2011
A massive crowd in Tunis protests the government, forcing Ben Ali to flee to Saudi Arabia.

JANUARY 21, 2011
Inspired by the toppling of Tunisia's president, the Muslim Brotherhood in Jordan leads thousands of demonstrators in a march on Amman, demanding economic and political reforms from King Abdullah II.

JANUARY 25, 2011
Thousands take to the streets in Egypt to call for an end to the regime of President Hosni Mubarak. Over the following weeks, hundreds of thousands of protesters occupy Cairo's Tahrir Square, making it a symbol of revolution in Arab countries.

JANUARY 27, 2011
Over 10,000 protesters in impoverished Yemen march against the regime of President Ali Abdullah Saleh.

FEBRUARY 11, 2011
Mubarak resigns after 18 days of protests against his regime.

FEBRUARY 12, 2011
Pro-democracy activists assemble in the Algerian capital to demand reforms from the government of President Abdelaziz Bouteflika.

FEBRUARY 14, 2011
Demonstrations begin in Bahrain, calling for an end to the monarchy of King Hamad bin Isa Al Khalifa.

FEBRUARY 15, 2011
Large-scale protests against Libyan dictator Muammar Gaddafi begin. They quickly spread and intensify until the country plunges into civil war.

FEBRUARY 20, 2011
Using Facebook to organize, Moroccan activists stage protests demanding constitutional reforms to break the autocracy of King Mohammed.

MARCH 15, 2011
Simmering discontent with the Baathist regime of Bashar Assad boils over when Syrians hold a "day of rage" in Damascus and Aleppo.

MARCO SALUSTRO/CORBIS (BOUAZIZI); KHALED DESOUKI/AFP/GETTY IMAGES (EGYPT); AP/KEVIN FRAYER (GADDAFI)

directed to e-mail Foetus, who didn't know him personally. Foetus decided on the basis of a Skype call to trust the source. Takriz leaders knew that Ben Ali would cut off the area as he had during the 2008 protests in Gafsa, so they rushed more Taks in to get there before road and Internet access was severed.

This poor interior region, far from the wealth of the capital and coastline, is hardscrabble territory. The people are tough: when one Tak was killed there, his mother, who has half a dozen sons working the fields, responded on a Takriz video by saying, "Even if I lose all my sons, I don't care." Protests and riots there have traditionally focused on issues such as unemployment. But Takriz tried to redirect them toward a particular end: removing Ben Ali.

MOLOTOVS AND STUFF

"We were online every day," says Foetus, "and on the streets pretty much every day, collecting information, collecting videos, organizing protests, getting into protests." Some met in person, in and outside Tunisia. Others logged in to an emergency online space. "We met

using Mumble [which is open-source, uses digital certificate authentication, and is regarded by Takriz as more secure than Skype]. We had minutes so people who couldn't make the meetings knew what was going on. We gathered information, bypassed censorship, channeled it on Facebook, scanned articles in the foreign media. We were in touch with the labor unions. We worked with everybody, we filled protests with people." Takriz also helped on the ground "with Molotovs and stuff," says Foetus. When the group put an instructional video for making a Molotov cocktail online, many thought it had crossed a line; but Foetus, though he does see a role for peaceful marches (not least to counter claims that protests were simply the work of "violent elements"), remains unconvinced that nonviolent methods alone would have expelled Ben Ali.

At a protest in Sidi Bouzid on December 22, Houcine Falhi shouted "No to misery, no to unemployment!" before fatally electrocuting himself. Two days later, a protester was shot and killed in a small town between Gafsa and Sidi Bouzid. As the troubles spread, the regime attempted to steal all the Facebook passwords in the country. On December 27, thousands rallied in Tunis. The next day Ben Ali sacked the governors of Sidi Bouzid and two other provinces, as well as the ministers of trade and handicrafts, communication, and religious affairs. He also visited Mohamed Bouazizi in a burn unit, in an attempt to display compassion. Addressing the nation, Ben Ali threatened to punish the protesters.

On December 30, a protester shot by police six days earlier died. Lawyers gathered around the country to protest the government and were attacked and beaten. On January 2, the hacking group Anonymous began targeting government websites with distributed denial-of-service attacks in what it called Operation Tunisia. As the academic year started, student protests flared. A flash mob gathered on the tracks of a Tunis metro and stood, covering their mouths, eloquently silent. On January 4, Bouazizi died of his burns. The next day, 5,000 people attended his funeral.

January 6 brought the regime's response to the Anonymous attacks: several activists were arrested. Seven cars of police in balaclavas arrested the prominent student activist and former bodybuilding champion Sleh Dine Kchouk, a member of the Tunisian Pirate Party, which is part of an international movement that seeks to reform copyright and patent law. Another target was rapper Hamada Ben Amor, known as El Général, whose song "Head of State" (sample lyric: "Mr. President, your people are dying") had been released online a week earlier.

Cyber-activist Slim Amamou was also arrested, and he used the location-based social network Foursquare to reveal that he was being held in the Ministry of the Interior. Both Kchouk and Amamou were interrogated about Takriz. The next day, 95 percent of Tunisia's lawyers went on strike. The day after, the teachers joined in. The following day, the massacres began.

TURNING PROTESTS INTO REVOLUTIONS

Over five grisly days starting on January 8, dozens of people were killed in protests, mostly in towns like Kasserine and Thala in the poor interior. There were credible reports of snipers at work. These deaths would turn the protests into outright revolution. One graphic and deeply distressing video was highly influential: it shows Kasserine's hospital in chaos, desperate attempts to treat the injured, and a horrifying image of a dead young man with his brains spilling out.

"It was really critical," says Foetus. "That video made the second half of the revolution." Posted and reposted hundreds of times on YouTube, Facebook, and elsewhere, it set off a wave of revulsion across North Africa and the Middle East. Like thousands of Tunisians, Rim Nour, a business consultant, was "online almost 24 hours a day," spending a lot of time identifying government stooges on Facebook groups. She remembers the video vividly: "A friend put it up and wrote something like 'You don't want to see this, it's horrible, but you must. You have a moral obligation to look at what is happening in your country.'"

"A medical-school student took it," says Foetus. "The doctors said 'Don't film,' and he said 'Fuck off' and filmed it. The regime had cut Internet service to Sidi Bouzid, so according to a Tak who asked to remain anonymous, Takriz smuggled a CD of the video over the Algerian border and streamed it via MegaUpload. Foetus saw the video and found it enraging. Takriz then forwarded it to Al Jazeera.

Al Jazeera reaches a global audience, and populations Facebook cannot: the poor, the less educated, the older. The network's Tunisian correspondent Lotfi Hajji recalls broadcasting live from his house "while the police were in front blocking me from going out to cover events." To him, Al Jazeera gained a competitive advantage by being "flexible," especially when using "fertile sources of content" like Facebook and other social media.

What the streets lacked in strategy and organization, they made up for in bravery. When someone was killed in a neighborhood, others "would turn and go 'what shall we do?'" Foetus says. "It's

"We gathered information, bypassed censorship, channeled it on Facebook," Foetus says. As the troubles spread, the regime attempted to steal all the Facebook passwords in the country.

like a decentralized direct response. So they'd go burn something. Then the day after were the funerals. Then they'd fire some gas bombs. Then we'd fight again. Then the night would come, and it would go on."

FACEBOOK MEETS THE STREET

"Facebook is pretty much the GPS for this revolution," says Foetus. "Without the street there's no revolution, but add Facebook to the street and you get real potential." During the revolution, Takriz had about 10,000 friends on Facebook. These were the active members, who didn't care about the risk of befriending Takriz in public. Before the revolution, others were afraid to "like" certain pages or found that some people would unfriend them for having "liked" a dissident page. Today, Takriz has over 70,000 Facebook friends (perhaps one in 30 of the Tunisians on Facebook), even though it continues to attack the interim government. The government response to those attacks: censoring the Facebook page and sending the interior minister on national television to denounce Takriz (without, of course, using its unacceptable name).

In a paper published in the *North Africa Journal*, Tunisian virtual-reality scientist Samir Garbaya of the Paris Institute of Technology looked at Facebook posts during the revolution. He wrote a script, using semantic search techniques based on keywords related to ongoing protests, to measure how much time it took for posts to result in responses like comments. In November, the average was four days. The day after Bouazizi burned himself: eight hours. On January 1: two hours. As Ben Ali left: just three minutes. Garbaya uses the term "Streetbook" to refer to "the transfer of the interaction from social networks to manifestation in the real world, on the street." That transfer, too, was speeding up.

On the street, the revolution was now intensely real. "Our motto," says Foetus, "was 'Don't talk, don't fucking analyze; get to the street, go fight.'" In real life, dozens were dying, hundreds injured. The street fighters included battle-hardened Taks and Ultras. "You had these old people who went for peaceful protests that last 30 minutes each day, then the tear bombs start and they go home," he says. But the Takriz guys stayed: they knew that Ben Ali had to go, "or we're dead."

The revolutionaries wanted to "fuel the rage" until the entire population was protesting on the street; they knew that even the biggest protests measured in the tens of thousands. "To overcome that deficit," argues Foetus, "you had to get the police to surrender." Takriz uploaded pictures of burning police stations to Facebook. Many police handed their arms to the military and stayed at home. But not all: those who remained at their posts were loosed on the population. For three days they shot from cars while snipers shot from rooftops. The government now denies that these snipers existed, but witnesses remember seeing protesters with neatly drilled heads, and there are videos.

On January 13, Ben Ali threw the dice one last time. Speaking in dialect instead of formal Arabic, he expressed "very, very deep and massive regret" about the people his regime had just killed, and he offered to stand down in 2014. The opposition cautiously welcomed this. It wasn't enough. Takriz uploaded a carefully drafted formal resignation letter by Morjane, in three languages, to KamelMorjane.com. Several international media outlets, and many Tunisians, took it seriously.

The next day, a massive crowd gathered in Tunis. Takriz hoped to use the size of the protest to help seize the Interior Ministry, but as the tear-gas bombs exploded, a lot of protesters melted away. A couple of hundred Tak Ultras tried to push on, without success. TAK Kram, a particularly hard-core Ultra group, split off and headed to the presidential palace—but Ben Ali had already fled to Saudi Arabia.

Three hundred Tunisians had died—considerably more, proportionately, than would die in Egypt.

COPY, PUBLISH, SHARE

Twelve hundred miles to the east, in Alexandria, Hassan Mostafa was "hysterically happy" when he heard the news. He started texting: "Ben Ali gone. Possibility." Recipients understood the possibility he had in mind. He reached out to some of the hardened criminals, "murderers and drug dealers," he had met while imprisoned for his Khaled Said protest: their skills would prove useful in stealing police riot helmets and guns. Through them, Mostafa recruited an army of toughs from the poorest areas. The city of Alexandria is "like a cobra," he says. "Mubarak always feared us."

Mostafa knows technology has played a crucial role. "Before this social-media revolution, everyone was very individual, very single, very isolated and oppressed in islands," he says. "But social media has created bridges, has created channels between individuals, between activists, between even ordinary men, to speak out, to know that there are other men who think like me. We can work together, we can make something together." He recalls the April 6 movement spreading content via blogs and Facebook with the note "Copy, Publish, Share." He knew it was working when people he didn't know passed him printouts in the streets. Text messages were also used to call for protests, instructing recipients to "send to 10 people."

Deep in Karmouz, the slum on the spot where Alexander the Great first docked, no one is on Facebook. But a group I interviewed there—including an ex-convict named Sparky, an Ultra named Gamel, and Ahmed Rahman, known as "the Groom of the Revolution" because he rushed from his marriage to the protests—all recalled texts reaching their phones. Some of these messages called for protests, and others specified where to meet. They forwarded the messages.

There were also e-mails with attachments describing how to deal with the military—"an Ultra thing from Tunisia," remem-

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bers Kotb Hassaneen, another Alexandrian activist. Activists in Bizerte, a coastal port north of Tunis, confirm that the Egyptian revolutionaries sought their help via Facebook. Some of the tactics they shared, says Foetus, have roots in long-standing contacts with anarchist and international protest groups like Indymedia, the Antifascist Network, and CrimethInc. For example, the technique called "Black Bloc"—having protesters wear black clothing en masse for impact and anonymity, with padding and protection to reduce injuries—dates back to 1980 in Germany.

Activists also used social media to deceive the security forces, says Hassaneen. They would post meeting points online, then change them by phone shortly beforehand. And on the street, Mostafa's army sought to tie up the police by protesting continuously in poor areas. "They never got sleep for four days," he recalls. Mostafa was shot in the abdomen by security forces—some throwing petrol bombs—while storming the security service's building in an effort to stop the destruction of documents. (He recovered.)

Meanwhile, Alexandria's hackers set out to hack their own side, says Hassaneen. They probed the social-media and Facebook profiles of activists, testing for vulnerabilities. Facebook's administrators took steps to increase the security of Egyptian activists' profiles, according to a report on *Newsweek*'s Daily Beast website that cited Richard Allen, Facebook's director of policy for Europe.

The most vital Egyptian Facebook page was We Are All Khaled Said. In the run-up to the revolution, its hitherto anonymous admin, Wael Ghonim, who was Google's head of marketing for the Middle East and North Africa, flew from his home in Dubai to Egypt. In Cairo he was kidnapped off the streets by the regime and held incommunicado for 11 days. On his release, he appeared on Egypt's Dream TV and said, "I am not a hero. I only used the keyboard; the real heroes are the ones on the ground." Shown photos of protesters who had died, he wept. Overnight he became an international figurehead for the revolution. "Wael's role was to help market the revolution digitally," says Ahmed Maher, "but my role was in the streets. So we were sharing roles: one online, one offline."

FIGHTING THE FEAR

The Ultras were also on Egypt's streets. On January 24, the day before thousands planned to protest the Mubarak regime, the Ultra Facebook pages for Al-Ahly and Zamalek (Egypt's biggest teams, traditional rivals) sent out a message saying, in effect, "We're not political, we're not part of this as an organization—you as individuals are free to do whatever you want." The message was clear, says James Dorsey, the soccer blogger: "Go out and kick ass." Ultras received other signals, too. Zamalek Ultras, for example, got the private message "This is what we've been preparing for."

Ultras brought organization to the ensuing protests in Cairo's Tahrir Square, says Dorsey. It was there, he says, that tens of thousands of people reached "the limits of technology": they may have gathered in response to online communications, but once there, "they had no organization, they had no experience." Two groups did have experience, though: the Muslim Brotherhood and soccer fans. "[The Ultras] fought battles, they understood organization, they understood logistics and they understood fighting a street battle with the police," Dorsey says. "And in that sense they played a very key role in breaking the barrier of fear."

FOLLOWING THE PROTESTS A computer screen displays a Twitter feed related to protests in Egypt on January 27. The posts used a hashtag, #jan25, that referred to a crucial day of protests against the long reign of Egypt's president, Hosni Mubarak.

It's difficult to grasp that fear: you have to live it and breathe it. Asmaa Mahfouz, a 26-year-old protester, fights her fear with religious faith. A week before January 25, she organized a protest in Tahrir Square to mark the death of the first of four Egyptians who burned themselves in imitation of Bouazizi. She announced her protest online, even giving out her phone number. Just three people joined her—before three armored cars of riot police arrived. Released but still furious, she went home and made a vlog that went viral. In the video, she says: "If you think yourself a man, come with me on January 25 … Come and protect me, and other girls in the protest." She added, "Sitting at home and just following us on the news or Facebook leads to our humiliation … go down to the street, send SMSs, post it on the Net, make people aware … Never say there's no hope! Hope only disappears when you say there's no hope."

Mahfouz clearly remembers the moment she left her apartment to head to Tahrir Square on January 25. Her father asked her to stay, fearing he would lose her. Crying, he took her in his arms

PETER MACDIARMID/GETTY IMAGES

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and said, "If I don't see you again, remember I love you so much." As she walked, friends called her mobile phone to tell her no one was protesting. She told them not to call her until after 2 p.m., the time when they had agreed to act. At exactly 2, people around her reached under their clothes and pulled out Egyptian flags. "I screamed, 'Oh my God, I'm dreaming!'" she recalls.

In Alexandria, reporters got caught up in the excitement. Activists borrowed their connections to upload videos, says Hassaneen: "We used their Thuraya satellite phones. We uploaded videos, sent them to Tunisia, and they uploaded them to Facebook and to the Net." There were activist control rooms in London, Dubai, and Tunis. Mubarak shut down the Internet and mobile connections for five days, but that was an "idiot procedure," Hassaneen adds, "because all the people who felt digitally paralyzed marched into the streets. They were curious to know what was happening."

In summary, people used not only all the technology they had, but all the technology they could borrow.

The dispute is highly polarized, but understanding what Takriz, April 6, and similar organizations actually did, and how they did it, makes the argument between cyber optimists and pessimists less academic. Indeed, the fact that regimes go to such trouble to monitor, identify, capture, beat, torture, and jail young people using online tools suggests that they, at least, see the power of new media. Egypt's new regime, a military junta, feels sufficiently threatened by young bloggers to keep jailing them.

The young make up the bulk of these movements, and inevitably they bring youth's character to their fight for change. Youthful protests can feel messy and chaotic. They are sometimes fun. They are often innovative. Organizing or attending protests gets fitted between flirting, studying, and holding down a job. Action for this generation is as likely to be mediated through screens—whether on a cell phone or a computer—as face to face.

But for Nizar Bennamate, the 25-year-old cofounder of Morocco's February 20 movement, the street is where history happens.

The fact that regimes go to such trouble to monitor, identify, capture, beat, torture, and jail young people using online tools suggests that they, at least, see the power of new media.

A YOUTH REVOLUTION

The Arab Spring has sharpened an acrimonious debate in the United States and Europe about the uses and importance of technology in regime change.

Clay Shirky, a professor at New York University, is one notable optimist about the capacity of technology to foster social change. In his book *Here Comes Everybody*, he writes, "When we change the way we communicate, we change society."

The journalist Malcolm Gladwell, who called Shirky's book "the bible of the social-media movement," strongly disagreed in a story in the *New Yorker* titled "Why the Revolution Will Not Be Tweeted." Later, contemplating the protests on the streets of Egypt, he returned to his theme: "Surely the least interesting thing about them is that some of the protesters may (or may not) have at one point or another employed some of the tools of new media to communicate with one another. Please. People protested and brought down governments before Facebook was invented." The new testament of the skeptics is Evgeny Morozov's *The Net Delusion: The Dark Side of Internet Freedom*, which decries the "naive belief in the emancipatory nature of online communication." The particular tenor of Morozov's critique derives from his unsuccessful experience as a digital activist in his native Belarus, which Condoleezza Rice, the former U.S. secretary of state, called "the last true remaining dictatorship in Europe."

Like thousands of young Moroccans, Bennamate, who has often been beaten at protests, is unhappy with the corrupt Makhzen, the elite centered on King Mohammed V's court. The streets, he says, are where the action is, and where "the real change" occurs: "On Facebook and Twitter and social media we just speak [about] what happens. If nothing happens, Facebook and media have no utility." For Foetus, too, the street is of primary importance. He now wishes Ben Ali had not been toppled quite so quickly, "so we could have built stronger ties on the street and got more organized there."

Thousands of lives have now been lost, and many more people have been injured. Real change remains elusive: those replacing Ben Ali and Mubarak are mostly members of the same stale regimes. But something deeper and more universal has been achieved: voice. New ties are being made both virtually and on the street. Social and mainstream media have connected people to each other and to the world. The youth of an entire region are speaking out with whatever tools they have, from social media to feet on the ground. The buds of the Arab Spring are young and still in need of nurturing, but George Washington's observation may still hold true: "Liberty, when it begins to take root, is a plant of rapid growth." tr

JOHN POLLOCK IS A JOURNALIST WHO WRITES MOSTLY ABOUT AFRICA. HIS ARTICLE "GREEN REVOLUTIONARY," A PROFILE OF NORMAN BORLAUG, APPEARED IN THE JANUARY/FEBRUARY 2008 ISSUE OF *TECHNOLOGY REVIEW*.

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DED CARDIO
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PIECES OF HEART Petri dishes hold cardiomyocytes grown from induced pluripotent stem cells that were created by reprogramming the author's blood cells. The two middle dishes contain only water.

Photographs by GREG RUFFING

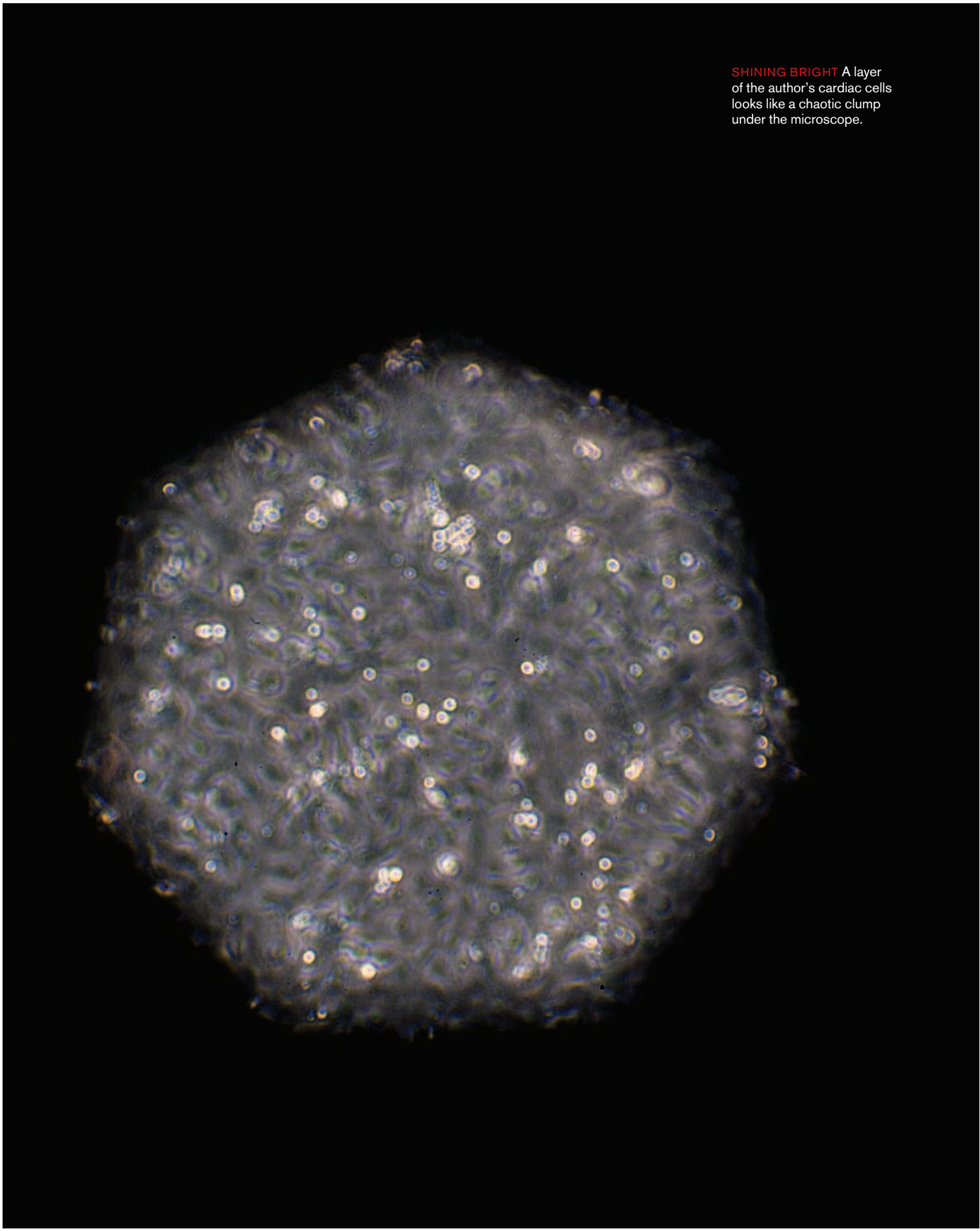
Growing Heart Cells Just for You

What can heart cells generated from my blood tell me about my risk for disease—and about what drugs I should take if I get sick?

By DAVID EWING DUNCAN

Peering through a microscope in Madison, Wisconsin, I watched my heart cells beat in a petri dish. Looking like glowing red shrimp without tails, they pulsated and moved very slowly toward one another. Left for several hours, I was told, these cardiomyocytes would coalesce into blobs trying to form a heart. Flanking me were scientists who had conducted experiments that they hoped would reveal whether my heart cells are healthy, whether they're unusually sensitive to drugs, and whether they get overly stressed when I'm bounding up a flight of stairs.

It was snowing outside the office-park windows of Cellular Dynamics International (CDI), where I was observing an intimate demonstration of how stem-cell technologies may one day combine with personal genomics and personal medicine. I was the first journalist to undergo experiments designed to see if the four-year-old process that creates induced pluripotent stem (iPS) cells can yield insight into the functioning and fate of a healthy individual's heart cells. Similar tests could be run on lab-grown



SHINING BRIGHT A layer of the author's cardiac cells looks like a chaotic clump under the microscope.

brain and liver cells, or eventually on any of the more than 200 cell types found in humans. "This is the next step in personalized medicine: being able to test drugs and other factors on different cell types," said Chris Parker, CDI's chief commercial officer, looking over my shoulder.

CDI scientists created the little piece of my heart by taking cells from my blood and reprogramming them so that they reverted to a pluripotent state, which means they are able to grow into any cell type in the body. The science that makes this possible comes from the lab of CDI cofounder and stem-cell pioneer James Thomson of the University of Wisconsin, the leader of one of two teams that discovered the iPS-cell process in 2007. (The other effort was led by Shinya Yamanaka of Kyoto University.) The results are similar to the special cells that appear in embryos a few days after fertilization.

Since late 2008, the company has been manufacturing cardiomyocytes and mailing the frozen cells on dry ice to academic scientists to study how these cells work, and to researchers in the pharmaceutical industry to use in early tests of drug candidates. One important reason to use the cells is that they could reveal whether drugs are toxic to the heart, information that other types of testing can miss. "Several drugs have made it to the market that have cardiotoxic profiles, and that's unacceptable," Parker says. He says that the cardiomyocytes derived from iPS cells are a huge improvement over the cadaver cells sometimes used to test potential drug compounds. Unlike the cadaver cells, IPS-generated cells beat realistically and can be supplied in large quantities on demand. What's more, iPS-generated cells can have the same genetic makeup as the patients they came from, which is a huge advantage in tailoring drugs and treatments to individuals. These made-to-order cells are not cheap, however. Cellular Dynamics' CEO, Robert Palay, says they cost about $1,500 for a standard vial of 1.5 million cells.

An especially sensational prospect is that iPS cells could be transplanted into patients so they could regenerate diseased or damaged spines, brains, hearts, or other tissue—a proposition that is particularly enticing because these cells wouldn't be rejected by the host's body. They could also defuse the political controversy around embryonic stem cells, because they may one day make it possible to harvest pluripotent cells without destroying a human embryo.

Transplantation, however, is years away for most tissue types, says Alexander Meissner, a Harvard University stem-cell researcher. "It's not trivial to regenerate brain tissue," he says. "This is going to take longer than people think." Thomson agrees. "Talk about transplantation has been a kind of irrational exuberance," he says. The process of using iPS cells to create new tissue still poses certain dangers: some cell lines, for example, harbor mutations that could lead to cancer, and in some cases cells retain a faint chemical memory of their previous identity as skin or blood cells.

Thomson believes these are temporary setbacks. "We have had bone marrow transplantation for a long time, which is essentially stem cells," he says. "And work is being done right now on using iPS cells to repair macular degeneration. But repairing damage to the nerves in a spine is much more difficult." Others share his cautious optimism. "Virtually everything about iPS cells is overhyped," says Chris Austin, director of the Chemical Genomics Center at the National Institutes of Health. "But for the purpose of testing drug candidates, I think the possibilities are considerable, and we and lots of other people are pursuing this. There are lots of problems. Are iPS cells really normal? How do you get enough pure differentiated cells? But the potential is definitely there."

STICKING TO SCIENCE

I first visited James Thomson on another snowy, frigid day in Wisconsin in 2008, a few weeks after the publication of his paper announcing iPS cells derived from human cells. A scrappy, no-nonsense man in a casual sweater and beat-up Dockers, he sat in a small office adorned with tropical fish, ferns, and an antique dartboard and discussed his original discovery of human embryonic stem cells in 1998. His work set off a storm of protest: opponents argued that destroying a human embryo to harvest its stem cells is tantamount to murder. President George W. Bush restricted most federal funding for embryonic-stem-cell research in 2001, and critics have continued to vilify Thomson, although he tries to keep a low profile. "I don't talk much about it," he said. "I stick to the science."

CDI scientists created the little piece of my heart by taking cells from my blood and reprogramming them so that they reverted to a pluripotent state, which means they are able to grow into any cell type in the body.

The creation of iPS cells in 2007 seemed like an elegant bookend to the 1998 finding, because it offered a new way to produce stem cells that can differentiate into any cell type—one that might actually be better, because the cells would be genetically identical to patients' own. "It was a relief that we might have a solution to this political and ethical situation," Thomson said. The breakthrough, however, was a surprise. "We knew that the iPS process was a possibility," he said, "but when we started out, I was sure it

would take 10 years at least." Thomson and a Wisconsin postdoc, Junying Yu, set out to create iPS cells by modifying skin cells with "regulator" genes normally found only in embryos. The method, he said, "surprised everyone by working."

Thomson cofounded CDI in 2007, around the same time that several other stem-cell luminaries became involved in iPS-cell companies. These would-be competitors, however, are primarily focused on creating therapeutics. They use iPS cells to help identify and develop drug candidates and to design processes that might one day lead to transplantation. So far CDI has no serious competitors in the market to sell iPS-generated cells in volume for use in research and drug screening. In part, this is because Thomson and his scientific team have been working longer to overcome difficulties in industrializing the technology. "Making iPS cells that are functional in large quantities is tough," says Harvard's Meissner.

Privately held, the company has not detailed its performance, but its CEO told a local newspaper that CDI gets "multimillions" in revenues from selling its heart cells to about 40 customers, including most large pharmaceutical companies. Next year the company plans to roll out iPS-generated liver, brain, and blood cells.

"This is a game-changer," says stem-cell biologist Sandra Engle, a senior principal scientist at Pfizer who has used CDI's cells. "Before CDI, these cells were very difficult to obtain, and we would only get tiny amounts. This doesn't work for high-throughput testing for drugs." For Kyle Kolaja, global head of predictive toxicology screens and emerging technologies at Roche, the benefit of the CDI cells is that they behave like "real" cells. "They are already having a major impact on drug safety and development," he says. "They have already changed what we're doing."

COLDHEARTED Samples of the author's cells are stored in trays under cryogenic conditions. University of Wisconsin biologist James Thomson (right) cofounded Cellular Dynamics International in 2007 after developing a method of reprogramming ordinary human cells to create induced pluripotent stem cells, which can give rise to any cell type. Thomson has since helped pioneer the use of iPS cells in drug development.

CELLULAR CLUES

Although companies like Roche and Pfizer are currently using iPS cells simply to screen potential therapeutics for toxicity and other characteristics, someday iPS-based tests could be performed on individual patients to see whether they are at particular risk for side effects. Euan Ashley, a cardiologist at Stanford University, is trying to use iPS cells to help diagnose and treat a 16-year-old boy with early symptoms of dilated cardiomyopathy, a potentially fatal disease in which the heart swells and weakens. "This is the sort of severe genetic disease that runs through families that we think can benefit from iPS technologies and genomics," says Ashley. He has scrutinized the boy's DNA for telltale genetic markers associated with the disease and has tested his brother and parents to see if they carry the markers as well. The Stanford team plans to create iPS cells by reprogramming skin cells taken from the family and then induce them to differentiate into cardiomyocytes bearing the characteristic genetic variations. By studying the biochemistry of these heart cells, the scientists hope to gain clues to how they might respond to various drug candidates.

"We will use the iPS cells to check the differences between this child and others with and without the condition," says Ashley, "and to test what drugs will work best for the boy and other impacted family members." Ashley says one goal is to develop tests to determine how the genetic variations actually affect the cells. "The importance of genetic factors will be reflected in these cells," he says.

Other clinicians and labs are also using iPS cells in experiments intended to shed light on disease. For instance, researchers at the Salk Institute are studying iPS-derived neurons from people with schizophrenia to see how they differ from normal neurons, and they will examine what happens when the cells are exposed to antipsychotic drugs. At the NIH, a group is studying iPS-generated cells from patients with a fatal genetic disorder known as Niemann-Pick disease type C. Other researchers have proposed using iPS-generated cells to test the effects of toxic chemicals such as mercury and pesticides.

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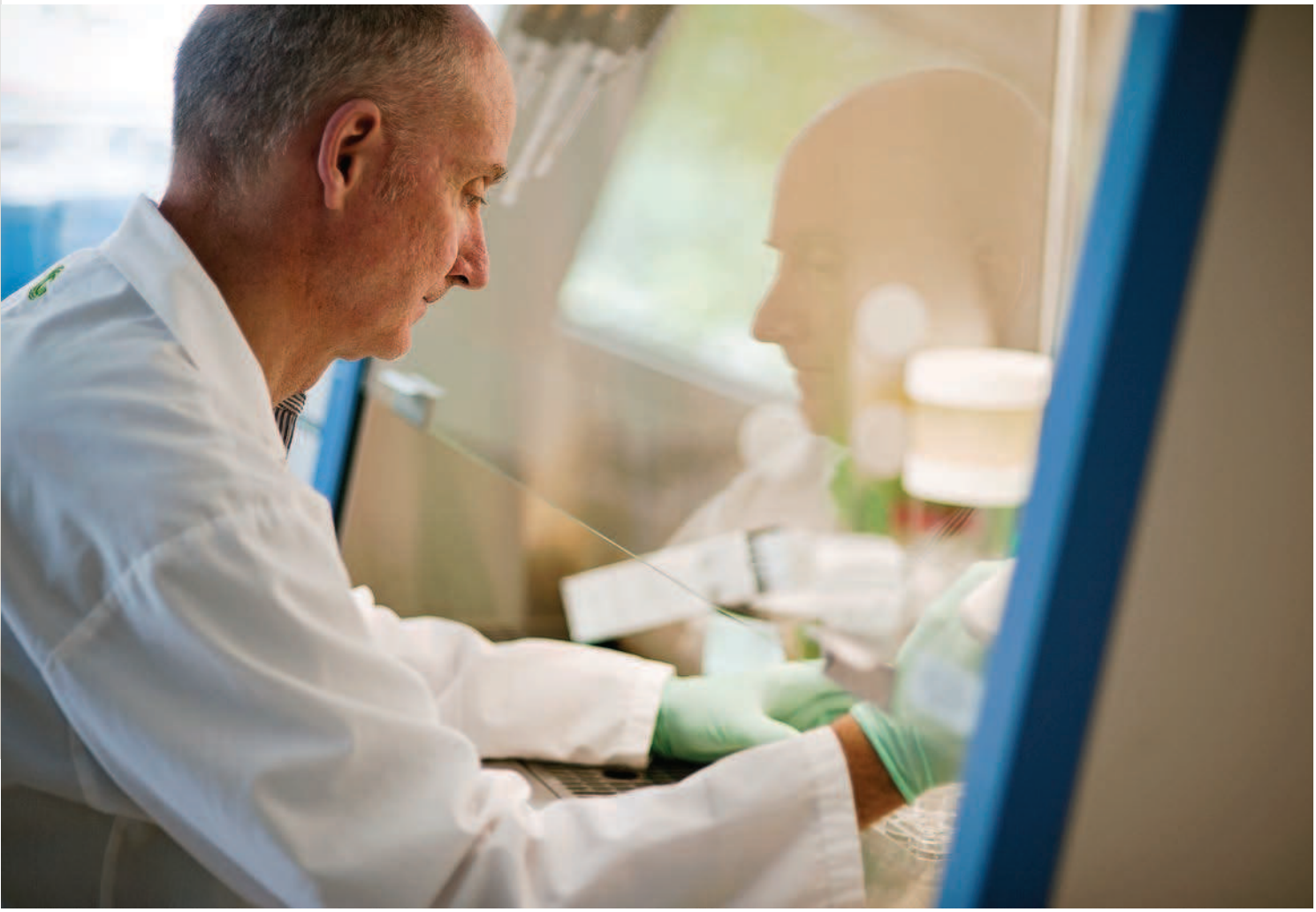

The hope, say researchers, is to create a library of iPS cell lines from people who have specific symptoms or behaviors associated with a particular disease. Roche has started a program with Massachusetts General Hospital in Boston to create cell lines that reflect different types of heart disease; the results could help the company develop drugs. This summer, CDI and the Medical College of Wisconsin announced a $6.3 million grant from the NIH to create iPS-generated heart cells from 250 patients who have left ventricular hypertrophy, a condition that causes high blood pressure and increases the risk for cardiovascular disease.

Scientists are still a long way from using iPS cells routinely to diagnose disease or offer individual prognoses. The NIH's Austin cautions that individual cells tell only part of the story of what happens in the dynamic system that is the human body. "In some cases, you don't have a cell that can give you a real answer about a disease like depression," he says. "What cell type do you use for that?"

MY MAMBO

I launched my own iPS journey in a small Quest Diagnostics clinic on a leafy street in San Francisco. Wrapping a rubber tube around my arm, the phlebotomist stuck in a needle to withdraw several vials of blood that would be shipped on ice to Madison. Once they got to CDI, technicians cracked open my white blood cells and used a bioengineered retrovirus to introduce "master transcription" genes into their DNA. These genes reprogrammed the cells so that when they replicated, the results were pluripotent cells rather than more white blood cells. Their transformation into functioning iPS cells took several months of coaxing, purification, and verification that cost about $15,000, which the company paid on my behalf. Once my pluripotent cell line was humming along, the scientists at CDI tweaked a few cells to make them differentiate into three types of heart cells—which I first saw pulsing in a video clip they e-mailed to me.

In Madison, nearly a year after giving up my blood, I was just a bit anxious as I stared at my beating heart cells. I was about to get a rundown on the experiments CDI had performed to demonstrate what these little bundles of bioengineered cytoplasm and nuclei might say about my health and my sensitivity to various drugs.

Chris Parker and the company's product manager for cardiomyocytes, Blake Anson, took the lead in walking me through a series

of assessments that began with tests "to make sure these cells are still you," said Parker. They showed me a slide of the 23 paired chromosomes taken from my original blood sample and compared it to a slide showing the chromosomes taken from the cardiomyocytes. They had also run a simple genetic comparison using 16 DNA markers, a test used by law enforcement that provides a quick, relatively cheap way to assess whether two samples match up. When my manufactured cells passed muster, the scientists moved to step two: seeing if they behaved like real cardiomyocytes.

First they buzzed the cells with electricity to check the range in duration of the action potentials—the electrical impulses that drive cardiac contractions. Then they measured the beats of the cells in the aggregate against a kind of EKG waveform like those that appear as up-and-down pulses on a hospital monitor. My cells appeared normal.

A third test pitted the cells against two drugs. One was epinephrine, which triggers the fight-or-flight response and speeds up a person's pulse. "We can see this here: beat, beat, beat," said Parker, showing me a slide with an EKG line. "Your heart rate increases dramatically, so that means you're okay—you can run from that bear." The scientists then dropped in a "sympathetic agonist," a drug that slows the heart way down. "So your cells can relax after running from that bear," said Parker. When I sent Euan Ashley my test results, he verified my persistent normalcy—and confirmed that the cells in question were what they were supposed to be. "These tests prove that the cells are cardiomyocytes," he said, "which at this early stage in this science is important."

A few weeks later, CDI ran another round of experiments that subjected my cells to drugs with known toxic side effects. First came Hismanal, an antihistamine, and Propulsid, a drug to treat gastrointestinal distress. Both medications were pulled from the market in many countries, including the United States, because they were associated with rare but potentially life-threatening heart arrhythmias. "This propensity is due to the unanticipated and unwanted side effect of both drugs blocking and disrupting the normal activity of a specific ion channel in the heart," said a report e-mailed to me from CDI. "Both drugs had similar effects on David Duncan's iPS-derived cardiomyocytes: a dose-dependent increase in the duration of the action potential … Prolonged action potential durations are a recognized trigger for cardiac arrhythmia that can result in sudden death."

For a second round of pharmaceutical testing, the scientists exposed my cells to two cancer drugs: Gleevec, used mostly to treat some forms of leukemia, and Sutent, used to treat tumors in the stomach, bowel, and esophagus. Both drugs have side effects that include damage to the heart, though they remain in use because the diseases they treat are so serious. "In vitro tests on David Duncan's iPS-derived cardiomyocytes demonstrated that both drugs had adverse effects," said my report, "and that the Gleevec-mediated effect may have been caused by disrupting mitochondrial function." Again, the reactions of my cells were not atypical, although the researchers told me that if I had cancer, further testing might turn up specific responses that could help a physician decide which medications were best for me.

Ashley told me that iPS-generated heart cells offer great potential as a way to test cancer treatments. "Chemo drugs are really hard on hearts, and on heart cells," he said. "If this technology can help, that will be really important."

CDI has told me that as the science unfolds, it may run tests based on the extensive DNA sequencing I had done for a recent book, *Experimental Man*. I'd be especially interested in a test that could determine how worried I should be about a genetic risk factor for side effects of cholesterol-lowering statins. According to my genetic profile, I have a substantial risk of myopathy—muscle weakness—if I take certain forms of these drugs. However, this condition is due to a malfunctioning enzyme produced by the liver, not the heart, so finding out depends on whether CDI is willing to create liver cells from my iPS line.

The reactions of my cells were not atypical, although the researchers told me that if I had cancer, further testing might turn up specific responses that could help a physician decide which medications were best for me.

Before I left the CDI lab, I took one more look at my heart cells pounding away in their petri dish in a sort of freakish mambo, and I wondered when such banks of individual cells would become a routine part of medical care. Many obstacles remain before this can happen, including the high cost of making the cells. Yet despite the expense, says Thomson, "there will be people that will want to do this—wealthy early adopters who want to know about a disease or a drug. Or some people might do it because they think having their beating heart cells is cool."

As for me, I'm still amazed that the cardiomyocytes in the dish are part of me—let alone that they might one day be used as stunt doubles for my real cells. tr

DAVID EWING DUNCAN IS A SAN FRANCISCO–BASED WRITER. HIS MOST RECENT BOOK IS *EXPERIMENTAL MAN: WHAT ONE MAN'S BODY REVEALS ABOUT HIS FUTURE, YOUR HEALTH, AND OUR TOXIC WORLD.*

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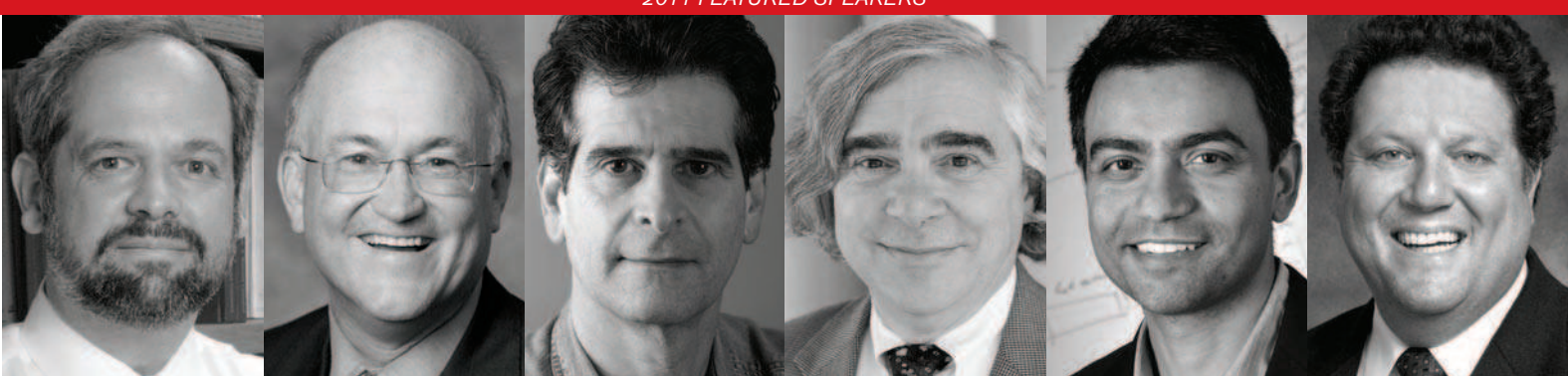

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HOW TECHNOLOGY IS CHANGING BUSINESS

The Future of the Office

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The explosion of mobile devices and social technologies means the office can be almost anywhere. In this issue and online, *Technology Review* examines the trend and its implications for productivity and security.

THE BIG QUESTION

The Rise of the Virtual Office

By ANDREW MCAFEE

The idea that the office is a specific place where our professional lives happen is becoming less universal, and less important. These days many knowledge workers can be productive anywhere, thanks to smarter, more numerous mobile devices, faster network access, and a growing number of online collaboration tools. And wherever the office may be, wider and better use of social networks, data analytics, and technologies such as voice recognition could be poised to increase productivity dramatically—meaning that both real and virtual offices may have fewer people in them.

But while the physical office is changing, certain connotations of the word "office" are

ON THE GO Andrew McAfee says that even though work can be done anywhere, face-to-face interaction will remain crucial.

not. I can think of at least two—"hierarchical organization" and "place for human interaction"—that are not becoming any less important. Even the most progressive high-tech companies retain organizational trappings of their industrial-age predecessors: full-time managers, org charts, job descriptions, and so on. And since humans remain social animals, gathering places will remain important in business. These spaces—whether they be conventional offices, temporary ones, or conference facilities—must be made conducive to collaboration. They must also become physically healthy places to spend hours of time, since sedentary work has emerged as a significant health threat.

As the office expands beyond its conventional boundaries, key challenges must be met, including the privacy and security issues posed by a distributed workforce of people who use multiple digital devices. New tools like cloud-based office productivity apps must be made not only user-friendly but resistant to attacks and data loss. And workers will need better tools—including improved voice-recognition software, e-mail-organizing technologies, and intelligent agents that help handle complex tasks once reserved for specialists—to streamline work processes and make sense of the overwhelming volumes of data besieging them.

To date, IT-driven productivity gains within the office have been modest, at least compared with those seen in manufacturing. In 1989 the U.S. manufacturing sector employed 18 million people; by 2009 that figure had declined to 11.8 million. But though the workforce shrank 34 percent, the value added by U.S. manufacturers—the value of their output minus the cost of raw materials purchased—surged 75 percent. We've observed white-collar productivity improvement as well, especially since the mid-1990s, but it hasn't been as big.

That may soon change. Consider that people already routinely deal with computers rather than office workers when they make an airline reservation, buy products and arrange for delivery, or troubleshoot a problem with a product. If a task involves simple and predictable forms of communication without much nuance or emotion, computers can do just fine, leaving humans to handle an ever-dwindling number of exceptions to the usual procedures or questions. More far-out advances in artificial intelligence could push productivity even further. Voice recognition, speech synthesis, and automatic translation have improved significantly. And we've seen that computers can now accurately understand and reply to questions: IBM's Watson supercomputer beat human competitors at *Jeopardy!* this year. Skeptics will point out that futurists have been promising an AI-driven revolution in knowledge work for decades. But by now even the skeptics are finding phone numbers with the help of computer operators. When the productivity enhancements from these innovations are tallied, I predict, they will be striking.

On top of this, software and social tools can boost the productivity of the remaining human office workers. For example, a customer-service rep who answers technical questions can work with just one customer at a time on the phone, but it's easy to handle two or more simultaneously if the medium is instant messaging. Whole office-based industries may become vastly more efficient. The legal profession, for one, may be in the early stages of a deep transformation. A new breed of legal outsourcing offers much cheaper ways to accomplish certain tasks: contract lawyers and digital tools scan documents during discovery processes, for example. Intelligent software will only get better at finding associations in those documents and mining meaning from it all.

One of the biggest barriers to higher office productivity was articulated best by the late Lew Platt when he was CEO of Hewlett-Packard: "If only HP knew what HP knows, we'd be three times more productive." Most organizations, in other words, do a lousy job of capturing relevant information and sharing it among all the people who could benefit from it. But the digital tools available to address Platt's frustration have gone from inadequate to industrial-strength in the past few years. They include blogs and microblogs, social-networking software, and wiki-style tools that allow collaboration without tightly constraining it. They give individuals a voice, allow groups to form easily and

EVGENIA ELISEEVA

spontaneously, and help knowledge spread. They will be a major force shaping office work in the coming years.

For that to happen, devices and data need to be secure. The prevalence of tablets and smart phones presents a double-edged sword. They help an employee get work done anywhere—but company data goes wherever the worker goes, and the company can't easily control it. A manager wants to be able to lock you out of your mobile devices if you are fired, so you can't pilfer anything. And a chief information officer doesn't want you downloading malware.

For some companies, the iPad model solves the latter problem: no application can run unless Apple reviews and blesses it. Internet-freedom purists may not like that, but CIOs do; they want to sleep soundly at night. In the near future, however, the major mobile platforms will probably introduce some interesting solutions that preserve the benefits of mobile and social computing while imposing security constraints that limit the risk to company data. When the security issues get sorted out, we may finally achieve the full potential of the distributed workforce.

Even as technologies proliferate and their problems are overcome, offices—no matter how virtual—remain collections of people. In my work, I've seen a positive feedback loop between what we do when we get together face to face and the ways in which we reinforce those relationships digitally with new tools.

And it's important to remember that even in this world of freelance and part-time contractors, companies are still desperate to hire good people and retain them. That's not going to change anytime soon, no matter how many snazzy digital tools we get. The office of the future might have fewer people in it, but the ones who are there will matter more than ever. BI

ANDREW MCAFEE IS PRINCIPAL RESEARCH SCIENTIST AT THE CENTER FOR DIGITAL BUSINESS AT MIT'S SLOAN SCHOOL OF MANAGEMENT AND AUTHOR OF *ENTERPRISE 2.0: NEW COLLABORATIVE TOOLS FOR YOUR ORGANIZATION'S TOUGHEST CHALLENGES.*

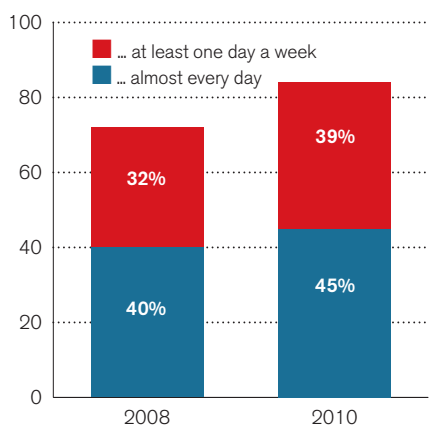
INFOGRAPHICS

Offices Go Mobile

Mobile devices are changing employees' expectations about when, how, and where they'll work.

The number of white-collar employees working from outside the office has been increasing.

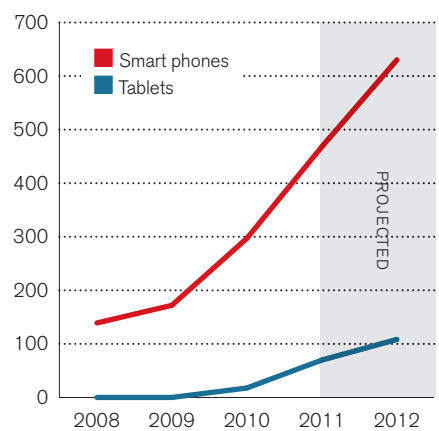
Employees who say they telecommute ...



Source: WorldatWork employee surveys

And consumers are buying smart phones and tablet computers at a brisk rate.

Mobile-device sales (millions)



Source: Gartner

Employees in office jobs have high expectations for using mobile devices—including their own—at work.

Measuring employee attitudes

66%
Expect to be able to use any device—personal or company-owned—to access corporate networks

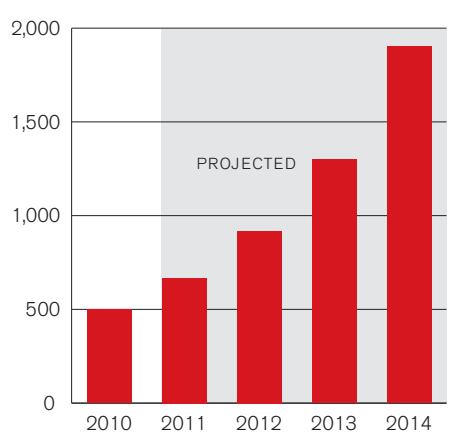
66%
Would take a job with less pay if they got more flexibility in their access to and use of mobile devices

60%
Believe it's not necessary to be in the office to be productive

Source: Survey commissioned by Cisco of 1,300 workers in 13 countries

Partly to capitalize on this trend, employers are adopting social technologies that allow employees to share and collaborate.

Worldwide business spending on social platforms (millions of U.S. dollars)



Source: IDC

EMERGED TECHNOLOGIES

Smashing the Cubicles

By designing new spaces around tablets, smart phones, and social technologies, companies can operate with far fewer desks.

By TOM SIMONITE

The quick expansion of social and mobile technologies is creating a widely distributed workforce. To better suit employees who come into offices more sporadically, some companies and design firms are testing radically new and more efficient configurations for physical offices, betting that improved technology will make the experiment more successful than similar ones in the 1990s.

A project at the headquarters of Cisco Systems in San Jose, California, for example, overthrows decades-old conventions about office space. Called Connected Workplace, it replaces individual cubicles with open clusters of wheeled desks that belong to groups, not individuals; personal belongings are largely confined to lockers.

There are no PCs at the desks, because employees use mobile technologies, including the Cius tablet, which Cisco recently began selling to businesses. Rick Hutley, a Cisco vice president, chooses his desk according to which colleagues are present and what's on the day's agenda. Then he docks his Cius to a desktop port that includes a phone handset. The tablet handles voice and video calls whether it's docked or mobile, and it can be used to share documents at meetings.

It can also be plugged into a monitor and keyboard to be used like a full PC. "You can walk around with your entire world with you in this device," Hutley says. "My laptop would often stay on my desk, but the tablet never does." If he needs to make a private voice or video call, he can step into one of the rooms at the edges of the cluster.

Employees can also participate in the company's corporate social network, Quad, which is accessible on the Web or through the iPhone, iPad, or Cius. People can post meeting requests, give status updates on projects, and quickly get in touch via instant messages, voice calls, or e-mail.

Cisco's vision is an example of a broader effort to reshape office technologies and environments. "We used to have boring stuff at work and more interesting technology at home," says Prith Banerjee, leader of Hewlett-Packard's research arm. "Now office technology will make use of the same cool experiences and interfaces."

Among other things, Banerjee predicts that flexible, paperlike color displays will eventually blur the boundary between phones and tablets, creating mobile devices better suited to serving as an entire office.

Such changes could save a lot of money. Cisco's project, for example, was launched after an internal study found that cubicles were vacant two-thirds of the time while people roamed the campus or worked remotely. Company calculations show that the building used for the project can accommodate 140 employees, up from 88 in designs used in traditional Cisco buildings, and that real-estate costs should drop by 37 percent.

Over the long term, Cisco hopes to save on health costs, too, because people who move around more frequently are less likely to suffer health problems. The company is planning to study whether the more mature technology of today can conquer resistance that hobbled previous attempts to build offices with little private space.

Meanwhile, office design firms are stepping in with complementary ideas. Steelcase, for example, is building office installations that allow for spontaneous meetings and collaboration. Mobile-device ports are built into conference tables or semiprivate pods, and some allow people to take turns projecting data on a common screen. BI

COURTESY OF STEELCASE

DESIGNED FOR MOBILITY This conference table, from the design firm Steelcase, allows employees to dock their mobile devices and take turns on the displays at the ends of the table.

Sophie Vandebroek

CHRISTOPHER LAMARCA/REDUX

LEADERS

New Technology Brings Offshoring to Villages

The Xerox CTO describes research that allows manufacturing and office workers to avoid commuting to traffic-choked Indian cities.

The next decade will bring remarkable changes in the way office work is done. Perhaps nowhere will change be more profound than in countries such as India, where improved network access and smart technologies could make it possible for certain tasks to be divided among people working in rural areas and other places outside major city centers.

Xerox is one of many companies researching this trend and developing the technologies that will pave the way. CTO Sophie Vandebroek described some of the efforts of the company's two-year-old Xerox Research Center in India with *Technology Review*'s chief correspondent, David Talbot.

_TR_: Offshoring is already a big business in India. What's coming?

Vandebroek: India today has large office buildings where you might find 3,000 people coming to a crowded urban area to perform tasks like document management or to staff a customer-call center. They have low incomes and sometimes commute for hours. It is better to spread that work into the villages—better for business efficiency, for sustainability, and for improving the health and happiness of the employees and their families.

Xerox employs ethnographers to study such problems. What's an example of what they've discovered?

One involves distributed manufacturing. In Chennai we studied a mass-producer of baskets and other woven goods. A rural coördinator would go around all week to the villages where the products were made, and on weekends he would enter production data into an Excel spreadsheet back in Chennai. He needed a way of entering and accessing data with his mobile phone in real time.

Such technology doesn't exist already?

If you are somewhere with sufficient bandwidth and a smart phone, you can access databases and even enterprise resource management systems. Innovation in the developing world is often about doing more with less—in this case doing specific things with less bandwidth on more phones. The new tool enabled access to only the specific real-time data he needed, which had been entered in Chennai.

Are such innovations applicable outside the developing world?

If you can do things in a simpler and more efficient way, it's always good. In the medical field, for example, there is a lot of innovation on low-cost devices that nurses can use in villages. Similar low-cost technologies could be used by people in the developed world to report their own medical information from their homes.

How can you break up the tasks of those massive offshoring centers and do it in villages, especially if the work involves sensitive financial or health information?

You need to do it securely, and in a way that can withstand breakdowns in village power and cellular or Internet connections. We are in the middle of crafting the solutions. For example, if the job involves managing your health-care payments—900 million health-insurance payments are processed by Xerox every year—we make sure we split the job, so that no one person knows your name, your medical condition, and your Social Security number.

How soon can such office solutions be widely implemented—and what's the ultimate vision?

My hope and goal is that this works and is scalable. We are initiating a pilot with one of the startups in the Indian Institute of Technology Madras's Rural Technology and Business Incubator. If it is successful, the future of work in India and in all developing nations will be radically different. It will allow people to make a living in their village and create a more socially and environmentally sustainable world. BI

EMERGED TECHNOLOGIES

Tiny, Cloud-Powered Desktops

The profusion of mobile devices is driving advances in cloud-based productivity apps built for the small screen.

By ERICA NAONE

When smart phones first took off, many software companies figured people might want to view files on the small screens, but few thought anyone would use them for creating, editing, and commenting on documents, spreadsheets, and presentations. "We were proven wrong," says Raju Vegesna of Zoho, a company that offers online office tools.

Businesses are demanding things like spreadsheet and document editing tools that work anywhere, on any device. In response, large and small companies are now providing cloud-based office-productivity applications for smart phones and tablets.

SMALL SCREEN Editing on a smart phone is tough, but mobile workers want to do it.

It takes creativity to make them work. Web-based word processors such as Google Docs weren't initially able to process touch-screen input. Google had to rework Docs so that it was possible to edit from certain devices, such as those running recent versions of Android. Zoho is building apps for mobile devices to bridge that gap for its products, enabling those programs to interpret users' touch-screen "clicks." Meanwhile, IBM is testing software that can break up large spreadsheets into portions for different users, making them less unwieldy to update and edit on tablets.

Cloud-based office software has been around for several years, making shared editing easier because multiple users need only keep track of one file. But the cloud is even more important when people are working on mobile devices, which are switched or replaced far more often than are desk-bound PCs.

The cloud is the natural central storage site not only for the data but for the productivity applications themselves, says Rick Treitman, entrepreneur in residence at Adobe and director of product marketing for its Acrobat.com cloud-based office applications. Zoho's Vegesna notes that users expect custom apps tailored to the iPhone, the Android tablet, or whatever device they're working on.

Scott Johnston, group product manager for Google Docs and Sites, says that while the interfaces will look different on phones, tablets, and PCs, "I suspect we're going full-featured on every device." He believes that workers will eventually use tablets in place of laptops and demand productivity software that works just as well on them. Potential advances in touch-screen technology—such as ways to give users more tactile feedback—could also accelerate demand for such apps.

While Google offers primarily cloud-based apps with light offline capabilities, Microsoft recently launched a cloud-based version of its Office productivity software called Office 365, betting that users will see advantages in full-featured offline software that also allows for accessibility in the cloud. Microsoft reasons that people want more features than most cloud apps offer, and want to be able to work when network access is unavailable. BI

More on the Future of the Office

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Greener in the Green Mountain State
A look at how Vermont is working toward the "paperless office" goal

Microsoft's New Office Strategy
Research chief Craig Mundie describes future office concepts

Playing Office Games
U.K. agencies devise contests on social platforms to drive innovation

Monitoring Remote Workers
Companies mine data to establish employees' "digital character"

Infosys Builds a Social Network
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GETTY IMAGES

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ART

The Mind's Eye

Long preoccupied with technology, David Hockney is exploring a new artistic medium that uses high-definition cameras, screens, software, and moving images to capture the experience of seeing.

By MARTIN GAYFORD

One of your basic contentions, I say to the British artist David Hockney, is that there is always more to be seen, everywhere, all the time. "Yes," he replies emphatically. "There's *a lot* more to be seen." We are sitting in his spacious house in the quiet Yorkshire seaside town of Bridlington. In front of us is a novel medium, a fresh variety of moving image—a completely new way of looking at the world—that Hockney has been working on for the last couple of years.

We are watching 18 screens showing high-definition images captured by nine cameras. Each camera was set at a different angle, and many were set at different exposures. In some cases, the images were filmed a few seconds apart, so the viewer is looking, simultaneously, at two different points in time. The result is a moving collage, a sight that has never quite been seen before. But what the cameras are pointing at is so ordinary that most of us would drive past it with scarcely a glance.

At the moment, the 18 screens are showing a slow progression along a country road. We are looking at grasses, wildflowers, and plants at very close quarters and from slightly varying points of view. The nine screens on the right show, at a time delay, the images just seen on the left. The effect is a little like a medieval tapestry, or Jan van Eyck's 15th-century painting of Paradise, but also somehow new. "A lot of people who were standing in the middle of the Garden of Eden wouldn't know they were there," Hockney says.

The multiple moving images have some properties entirely different from those of a projected film. A single screen directs your

A still from the 18-screen video *May12th 2011 Rudston to Kilham Road 5 PM.*

attention; you look where the camera was pointed. With multiple screens, you choose where to look. And the closer you move to each high-definition image, the more you see.

"Norman said this was a 21st-century version of Dürer's *[Large] Piece of Turf*," Hockney says. By "Norman" he means Norman Rosenthal, the former exhibitions secretary of the Royal Academy in London and one of the doyens of the international contemporary-art world. The comparison is an intriguing one. Albrecht Dürer's 1503 drawing (*Das große Rasenstück* in German) was a work of great originality.

May 12th 2011 Rudston to Kilham Road 5 PM (2011)
"Brushes" drawings for the iPad
Pearblossom Hwy. (1986)
Luncheon at the British Embassy, Tokyo, Feb. 16, 1983 (1983)
by David Hockney

Das große Rasenstück (1503)
by Albrecht Dürer

Dürer used the media of the time—watercolor, pen, ink—to do something unprecedented: depict with great precision a little slice of wild, chaotic nature. He revealed what was always there but had never before been seen with such clarity. Hockney, in 2011, is doing the same job, using the tools of the moment: high-definition cameras and screens, computer software. Of course Hockney, too, is a painter—indeed, his grid of 18 flat screens, run by seven Mac Pro computers, looks much like one of his multipanel oil paintings. Except, of course, that every panel moves.

Hockney's technology assistant, Jonathan Wilkinson, explains how this 21st-century medium works. "We use nine Canon 5D Mark II cameras on a rig we've made, mounted on a vehicle—either on the boot or on the side. Those are connected to nine monitors. I set it up initially, taking instructions from David, to block it in. At that point we decide the focal length and exposure of each camera. There are motorized heads with which we can pan and tilt, once we've got going, while we're moving along. There's a remote system he can operate from the car."

Hockney compares that process to drawing. For him, drawing is not merely a matter of making lines with a tool; it's fundamentally about constructing a two-dimensional image of three-dimensional space. He argues that the same is true of putting photographic images together in a collage, and also of altering a single pho-

Above: Hockney "draws" with images from nine cameras (left). Jonathan Wilkinson, Hockney, and Dominic Elliott rig up the cameras (right).

Below: Stills from *Woldgate 7 November 2010 11:30 AM* (left) and *Woldgate 26 November 2010 11 AM* (right).

(ABOVE) JEAN-PIERRE GONCALVES DE LIMA/©DAVID HOCKNEY

tograph. Hockney complains that today's media are full of badly drawn (that is, Photoshopped) photographs.

The wild plants at the side of the road are only one subject. A number of other films chart the sequence of the seasons in the quiet corner of the English countryside where Hockney now spends much of his time. These too present a subject that is centuries old (the four seasons were a feature of medieval books of hours), but with a twist made possible by technology that became available only very recently.

They offer a lesson in the startling changes in vegetation, quality of light, and patterns of shadow that a few months will bring. The left-hand side will show, say, a progression down a country road in early spring, the right-hand side the same journey taken at exactly the same speed past the identical trees, fields, and bushes in high summer: the same, but utterly transformed. Because it is in practice impossible to drive at absolutely the same speed along a road in spring, summer, and winter, the precise synchronization of these sequences is achieved by editing. "Because we've done things at different times of the year," as Wilkinson puts it, "we remap time to get them in the same place simultaneously in each film."

THE CAMERA'S EYE

"A lot of people have told me," Hockney remarks, "that before they see these films they can't imagine what nine cameras could do that one can't. When they see them, they understand. It's showing a lot more; there's simply a lot more to see. It seems you can see almost more on these screens than if you were really there. Everything is in focus, so you're looking at something very complicated but with incredible clarity." In a way, this is a matter of multiplication: nine cameras see many times more than one.

Furthermore, Hockney believes that his multiscreen film collages are closer than conventional photography to the actual experience of human vision: "We're forcing you to look, because you have to scan, and in doing so you notice all the different textures in each screen. These films are making a critique of the one-camera view of the world. The point is that one camera can't show you that much."

You could say Hockney is using cameras to reveal the limitations of the camera. The films are the result of decades' thought about the place of old art forms—painting and drawing—in a world dominated by rapidly evolving photographic and electronic media.

Now 74, Hockney was born in Bradford, on the other side of Yorkshire, in 1937. It was apparent from early on that he was an exceptionally brilliant draftsman. Indeed, he belongs to one of the last generations of artists to receive a rigorous training

in draftsmanship before art education changed in the late 1960s.

Hockney started using photographs as a basis for paintings in the late 1960s. But he became dissatisfied with the direction his work was taking, which in some cases veered toward a form of photorealism. By the '80s he was conducting a personal research program into the nature of pictorial and photographic space. He began to entertain the idea that what the camera sees and what the eye sees are in some ways fundamentally different. "Most people feel that the world looks like the photograph," he says. "I've always assumed that the photograph is nearly right, but that little bit it misses by makes it miss by a mile. This is what I grope at."

A camera looks through one lens; we look—most of us, at least most of the time—through two eyes. Then we are not just looking *at* a scene from outside; we are always *in* it. People, you might say, are biological sensing devices, placed in an infinitely complex three-dimensional environment. What we see, subjectively, is always related to what we are interested in. Or, in Hockney's epigram, "The eye is attached to the mind."

In the early 1980s, Hockney began a series of composite or collaged pictures made from a mosaic of Polaroid snaps, including *Luncheon at the British Embassy, Tokyo, Feb. 16, 1983* and the several versions of *Pearblossom Hwy.* (1986). These were images with not one viewpoint but dozens, presenting—Hockney would argue—a representation of the world truer to experience than a single photograph. (Just as today he likens his multiple-screen images to drawing, he classified these Polaroid collages as drawings rather than photographs.) At the time, he wanted to make moving multiple-viewpoint images—and produced one for a television documentary—but the process was prohibitively complex and costly. Only in the last few years has the technology become available that allows him to do so with his own studio team, and in richly detailed quality.

Another result of this preoccupation with the role of lenses in the making of art was his book *Secret Knowledge* (2001). In it, Hockney argued that Western art had been affected by the lens-eye view for centuries before the official advent of photography in 1839. It had long been known that some artists had used the camera obscura—essentially, a filmless camera that came in portable or room-size versions (both Canaletto and Joshua Reynolds owned the former). But whereas conventional art history had tended to minimize this, Hockney maximized it.

Hockney is using cameras to reveal the limitations of the camera. The films are the result of decades' thought about the place of old art forms—painting and drawing—in a world dominated by rapidly evolving photographic and electronic media.

An artist of the Renaissance or Baroque eras might have used a camera image in many ways. For Canaletto, tracing the image onto paper was evidently a handy way of noting architectural detail (such drawings by him, with a telltale traced line, exist). But other painters might have learned from observing how a camera obscura simplifies highlights and shadows onto a two-dimensional surface. There are compelling resemblances between such projections and 17th-century painting. Once you've seen them it is hard to believe that Caravaggio, Van Dyck, and Dutch still-life painters hadn't looked through a camera obscura.

But there have always been ways to draw and paint that do not imitate cameras. Hockney reminds us that Far Eastern art, for example, has neither Renaissance-style single-vanishing-point perspectives nor shadows. The former is an optical property of a single-lens view; the latter result from the strong illumination that cameras tend to require.

The most recent of Hockney's nine-screen films were shot in his huge and light-filled Bridlington studio. They look

(BELOW) ©DAVID HOCKNEY

Pearblossom Hwy. (1986) and *Luncheon at the British Embassy, Tokyo, Feb. 16, 1983.*

like a cross between silent comedies and Chinese scrolls, filled with a characteristic range of astonishingly saturated color and—because of both the cameras and the light flooding through windows in the roof—without shadows.

ART AS TECHNOLOGY

An exhilarating aspect of Hockney's approach is that it widens art history into a unified account of pictures, images, of all kinds—handmade, photographic, cinematic, televisual. They are all part of the same story. He is, for example, strongly interested in the movies (after all, before coming to work in Yorkshire in 2000, he lived for three decades in Los Angeles, which he still calls his base).

A basic point for Hockney is that *all* art is based on technology. The paintbrush, as he says, is a technological device. And paint, a discovery tens of thousands of years old, can still produce an intensity of color that no screen or printing machine can equal.

Though drawing itself is a very old human technique—going back at least to the prehistoric cave paintings of southwestern France—Hockney has been adept at using new technology to find new ways to draw. In the 1980s he used early color

(TOP) COLLECTION: THE J. PAUL GETTY MUSEUM, LOS ANGELES/PHOTO: RICHARD SCHMIDT. ©DAVID HOCKNEY

Untitled, 30 November 2010, No. 1, created on an iPad.

photocopiers and fax machines to make art. Using the fax, he distributed art by telephone; with the photocopier he made prints that, paradoxically, could not be photocopied (if you make an intense black by putting the paper through the machine four times, it cannot be replicated by a single copying process).

During the last three years, he has been fascinated by the possibilities of drawing on, first, an iPhone and then—as soon as it appeared—an iPad. He had tried earlier forms of computer drawing but found them too slow for practical use. Now the iPad, plus an app called Brushes, is his medium of choice. He uses it as an electronic sketchbook; it is always by his side. A steady flow of iPhone and iPad drawings—loose, free, experimental, and intimate—pop, sometimes every day, into the mailboxes of his friends and acquaintances. More than 200 are currently in mine. They add up to a visual diary, recording sights that fall under Hockney's eyes as he moves through his day: the view from his bedroom window at dawn, the kitchen sink, a coffee cup, a candle burning in the evening. Looking at them gives clues to where Hockney is, how he's feeling, and what the current weather is like in east Yorkshire.

Recently he has begun printing Brushes drawings out at a large scale (this requires a program that prevents the images from pixelating, as they otherwise would). Early next year a sequence of these grand-scale iPad pictures will fill the largest gallery at the Royal Academy, where there is an exhibition of Hockney's new work depicting the very same Yorkshire landscapes that he films with his nine cameras and paints in oil. His work in all three media is interdependent. The paintings and drawings led on to the films, and the films in turn prompt new directions for the paintings and drawings.

All Hockney's work and thought is dedicated to the proposition that there is always *more* to see in the world around us. Art is a way—you might say a set of technologies—for making images, preserving them in time, and also for showing us things we aren't normally aware of. Those might include gods, dreams, and myths, but also hedgerows.

"Don't we need people who can see things from different points of view?" Hockney asks. "Lots of artists, and all kinds of artists. They look at life from another angle." Certainly, that is precisely what David Hockney is doing, and has always done. And yes, we do need it. tr

MARTIN GAYFORD IS THE CHIEF ART CRITIC FOR BLOOMBERG NEWS. HIS 2005 PORTRAIT BY LUCIAN FREUD, *MAN WITH A BLUE SCARF*, WHICH HAS BEEN EXHIBITED AT THE CORRER MUSEUM IN VENICE AND THE MUSEUM OF MODERN ART IN NEW YORK, WAS THE OCCASION OF HIS MOST RECENT BOOK, ALSO TITLED *MAN WITH A BLUE SCARF*. HIS NEXT BOOK, *A BIGGER MESSAGE: CONVERSATIONS WITH DAVID HOCKNEY*, WILL BE PUBLISHED IN OCTOBER.

ECONOMICS

Cryptocurrency

The bitcoin, a virtual medium of exchange, could be a real alternative to government-issued money—but only if it survives hoarding by speculators.

By JAMES SUROWIECKI

When the virtual currency bitcoin was released, in January 2009, it appeared to be an interesting way for people to trade among themselves in a secure, low-cost, and private fashion. The Bitcoin network, designed by an unknown programmer with the handle "Satoshi Nakamoto," used a decentralized peer-to-peer system to verify transactions, which meant that people could exchange goods and services electronically, and anonymously, without having to rely on third parties like banks. Its medium of exchange, the bitcoin, was an invented currency that people could earn—or, in Bitcoin's jargon, "mine"—by lending their computers' resources to service the needs of the Bitcoin network. Once in existence, bitcoins could also be bought and sold for dollars or other currencies on online exchanges. The network seemed like a potentially useful supplement to existing monetary systems: it let people avoid the fees banks charge and take part in noncash transactions anonymously while still guaranteeing that transactions would be secure.

Bitcoin
www.bitcoin.org

Yet over the past year and a half Bitcoin has become, for some, much more. Instead of a supplement to the dollar economy, it's been trumpeted as a competitor, and promoters have conjured visions of markets where bitcoins are a dominant medium of exchange. The hyperbole is out of proportion with the more mundane reality. Tens of thousands of bitcoins are traded each day (some for goods and services, others in exchange for other currencies), and several hundred businesses, mostly in the digital world, now take bitcoins as payment. That's good for a new monetary system, but it's not *disruptive* growth. Still, the excitement is perhaps predictable. Setting aside Bitcoin's cool factor—it might just as well have leapt off the pages of Neal Stephenson's cult science-fiction novel *Snow Crash*—a peer-to-peer electronic currency uncontrolled by central bankers or politicians is a perfect object for the anxieties and enthusiasms of those frightened by the threats of inflation and currency debasement, concerned about state power and the surveillance state, and fascinated with the possibilities created by distributed, decentralized systems.

Bitcoin is not going to make government-backed currencies obsolete. But while the system's virtues, such as anonymity and the lack of bank fees, may not matter much to most consumers, one can envision it being useful in a variety of niche markets (some legal, others not, like recreational drugs). Where anonymity is valuable, where trusted third parties are hard to find or charge high rates, and where persistently high inflation is a problem, it's possible that bitcoins could in fact flourish as an alternative currency.

Before they become such an alternative, though, the system will have to overcome a major, and surprising, problem: people have come to see it primarily as a way to *make* money. In other words, instead of being used as a currency, bitcoins are today mostly seen as (and traded as) an investment. There's a good reason for that: as people learned about Bitcoin, the value of bitcoins, in dollar terms, skyrocketed. In July 2010, after the website Slashdot ran an item that introduced the currency to the public (or at least the public enthusiastic about new technologies), the value of bitcoins jumped tenfold in five days. Over the next eight months, the value rose tenfold again. This attracted an enormous amount of publicity. More important, it also made people think that buying and holding bitcoins was an easy way to make a buck. As a result, many—probably most—Bitcoin users are acquiring bitcoins not in order to buy goods and services but to speculate. That's a bad investment decision, and it also hurts Bitcoin's prospects.

True believers in Bitcoin's usefulness prefer to deny that speculation is driving the action in bitcoins. But the evidence suggests otherwise. The value of the currency has been tremendously volatile over the past year. A bitcoin has been worth as little as a few pennies and as much as $33, and after seeming to stabilize at around $14 over the summer, the bitcoin's value tumbled by almost 50 percent in a matter of days in August. Media coverage has had an outsized impact on the value of bitcoins, even when it has not had a major impact on the number of transactions conducted. Blog posts in which people talk about buying bitcoins because of how much they've increased in value are common. In May, Rick Falkvinge, founder of the Swedish Pirate Party, which focuses on patent and copyright reform, posted that he had decided to put all his savings into Bitcoin. Although he had previously published a series of posts arguing for the bitcoin's viability as a currency, his first listed reason for investing in bitcoins was that their value had risen a thousandfold against the U.S. dollar in the previous 14 months. That's classic speculative thinking.

The problem with having the Bitcoin economy dominated by speculators is that it gives people an incentive to hoard their bitcoins rather than spend them, which is the opposite of what you need people to do in order to make a currency successful. Suc-

NICK VEASEY/GETTY IMAGES

cessful currencies are used to transact day-to-day business and lubricate commerce. But if you buy bitcoins hoping that their value will skyrocket (as anyone investing in bitcoins would), you're not going to be interested in exchanging those bitcoins for goods, since then you'll lose out when the value of bitcoins rises. Instead, you're going to hold onto them and wait until you can cash out.

This kind of hoarding is made more likely by the way Bitcoin is set up. Whereas the supply of modern, "fiat" currencies is controlled by central banks, the supply of bitcoins is permanently limited; there will never be more than 21 million bitcoins in existence. (The total number of coins is a result of the system's initial rules governing how many bitcoins miners could earn, and how often.) Bitcoin's limited money supply is one of the things that people like about it: the currency cannot be debased, as money can when central bankers print more of it. But the flip side is that if the demand for bitcoins rises, for whatever reason, then the value of bitcoins will necessarily rise as well. So if you think that bitcoins are going to become more and more popular, then—again—it's foolish to spend your bitcoins today. The rational thing to do is hoard them and eventually sell them to new users. But that means there will be fewer bitcoins in circulation (and more in people's virtual wallets), making them less useful as an actual medium of exchange and making it less likely that businesses and consumers will ever see Bitcoin as legitimate.

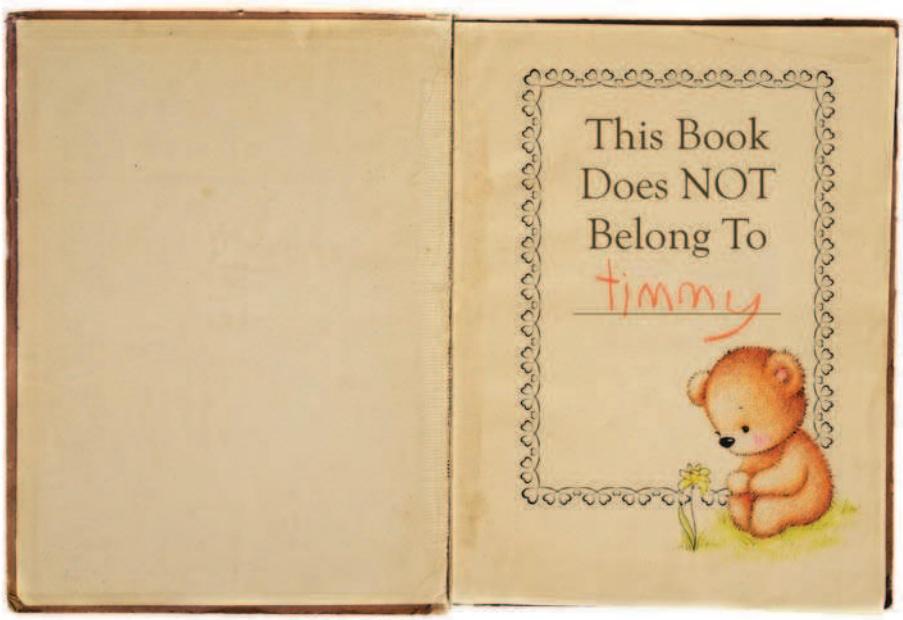
Now, even traditional currencies can be subject to this kind of cycle, which economists call a "deflationary spiral"—although with conventional currencies, the cycle occurs when falling prices lead people to start hoarding cash in the expectation that prices will keep falling (which in turn holds down demand and makes prices fall further). The quintessential recent case is Japan after its real-estate bubble burst in the 1990s.

With ordinary currencies, though, there's a limit to how far down the spiral can go, since people still need to eat, pay their bills, and so on, and to do so they need to use their currency. But these things aren't true of bitcoins: you can get along perfectly well without ever spending them, so there's no imperative for people to stop hoarding and start spending. It's easy to imagine a scenario in which the vast majority of bitcoins are held by people hoping to sell them to other people.

We may already be living in that scenario, since despite all the buzz about Bitcoin, the number of actual transactions conducted in bitcoins, and the value of those transactions, has been shrinking. According to bitcoinwatch.com, the best source of Bitcoin data, more than a million dollars' worth of bitcoins were traded on June 13. By early August, less than half a million dollars in bitcoins were being used in transactions; even the currency's value had been cut in half. Successful network technologies do not tend to see usage plateau, let alone shrink, this early in their history. And the lack of growth in the number of transactions conducted via Bitcoin is not what you'd expect to see if the technology were, as Falkvinge said, on its way to being a part of "normal daily commerce." It's true that there aren't all that many goods and services one can (or would want to) buy with bitcoins. But in a way, that's the real problem: a falling rate of use makes businesses less, not more, interested in accepting bitcoins, and ordinary consumers less interested in spending them.

So just now the bitcoin boom of the past year looks not so much like the birth of a new currency as like a classic bubble. And this has created a real paradox for bitcoin enthusiasts. The best thing for bitcoins would be for people to stop thinking of them as an investment and start thinking of them as a currency. That probably requires the bubble to burst, as it may be doing right now. But if the bubble bursts, it's possible that people's interest in Bitcoin will just fade away. After all, would you accept bitcoins in exchange for your work or products if you knew their value had fallen 50 percent in a matter of days? The challenge for Bitcoin now is whether, having become popular because of the cycle of hype, it can somehow avoid being devoured by it. Only then might we able to say, Good-bye, asset; hello, currency. tr

JAMES SUROWIECKI WRITES THE *NEW YORKER*'S "FINANCIAL PAGE."



MEDIA

A Cloud over Ownership

Online services set content free from the physical world's constraints—including those that have defined the very idea of possession.

By SIMSON L. GARFINKEL

Our possessions define us. Yet today the definition of possession itself is shifting, thanks to cloud services that store some things we hold dear on distant Internet servers. When those belongings reside in Netflix's video service, Amazon's Kindle bookstore, or Apple's coming iCloud service, they become impossible to misplace, and easier to organize and access than before. They also gain new powers over us, and slip free of powers we once held over them—powers that have shaped our thinking and behavior for centuries. One consequence is to give the companies that provide cloud services tremendous amounts of unchecked control over these possessions. In some cases, that control has already been abused.

Despite the supposed revolution wrought by digitization, mass computing has until now left the fundamental nature of our possessions untouched. Collections of content have adorned the shelves and walls of our homes, schools, and courts since the Enlightenment. Nearly all of us (who are old enough) collected vinyl records in the 1970s, videotapes in the '80s, CDs in the '90s, and DVDs in the '00s. Digitization simply morphed our urge to collect atoms into a thirst for curating bits, piled up on home computers.

In this age of streaming, however, possessing a personal content collection is a logical inconsistency. The 200 movies in my Netflix instant queue form an aspirational list, not a personal collection. Once I actually watch a movie, it disappears from the queue—the reverse of what happens on my shelf of DVDs. Personalizing a cloud-based collection of content is a pale imitation of what physical possession can offer. Even were I to show dinner guests my Amazon Kindle account, they wouldn't gain the insight provided by a glance at a shelf in my dining room or the stack of books on my nightstand. There will never be a well-worn copy of my favorite digital book.

Amazon Kindle bookstore
Apple iCloud
Google Music
Dropbox

Dissolving physical possessions into the cloud is certainly convenient. It may even make us less covetous and more inclined to share. But this new form of property is also shaping up to have more serious consequences than the loss of a few conversations. One is that those previously inanimate possessions can now talk about you behind your back. Watch a movie on Netflix or Amazon, and the company's servers know who you are and what you watch, when you watch it, where you're watching from (more or less), and even when you fast-forward. U.S. law prohibits the release of movie titles that a person has watched, but cloud providers can do pretty much whatever they want with the other data they collect.

Today providers use this information to improve their service and make recommendations; tomorrow your data could travel to third parties. Apple could combine its own data with commercial data banks to tell Beyoncé the number of men aged 25 to 30 who are buying her tunes in New York City, for example; the music you place in Google's cloud storage and playback service could shape the advertising that you see all over the Web.

The tattletale nature of things in the cloud comes from the fact that unlike practically every other object on the planet, cloud-things remain unbreakably tethered to their producer. This tether means they bear little similarity to property as we have conceived it for hundreds of years. Popular understanding of what it means to own something—be it digital file or physical object—has up to now been well aligned with the law's. When you buy a book you don't get rights to the text, but you can read it, lend it to a friend, and then sell it to a secondhand shop, which can advertise it and sell it once more. But this tacit understanding of ownership is useless in the cloud.

Consider what happened in July 2009, when Amazon discovered it had accidently sold improperly licensed e-books of George Orwell's *1984* and electronically obliterated them from every Kindle in existence. Win-

ston Smith would have felt right at home, but the laws of physics, physical property, and copyright would have made such a maneuver triply impossible with a conventional book. Amazon could never have sent guards to conduct house-to-house searches.

In the cloud we are ruled by contract law and whatever constraints our provider builds into the long legal screeds we must agree to in order to use their services. Some aspects of these contracts are necessary for a company to operate. But they also provide an opportunity to place complex conditions on our possessions. Yes, you may lend Amazon e-books, but only for 14 days at a time. You may delete your e-books, but you can't give them to a friend when you are done reading them. Publisher HarperCollins has decided that libraries may lend out e-books only 26 times before they must purchase a new copy. Other publishers prohibit lending entirely. Amazon's Orwellian vanishing trick demonstrates that cloud providers have considerable power to enforce such rules. The nuclear option is the simplest restriction of all: terminating your account.

Back when you owned your own collection, you didn't risk losing it because you had a billing dispute with the Book-of-the-Month Club, nor could a library fine threaten your family photos. Such scenarios are becoming possible as cloud services become more consolidated. Apple's iCloud will look after e-mail, books, music, photos you take, and documents you create; Google's cloud services span the same range and now also include a Facebook-like social network, Google+. A fight with a cloud provider that controls so many of your digital possessions is a daunting prospect.

Threats to a carefree cloud come from outside, too. A hacker might steal or delete all your files, perhaps with the help of a screw-up like one that for a short time allowed users to log in to Dropbox cloud storage accounts with incorrect passwords.

When the bits and atoms that make up your possessions are safely inside your house, the security measures that matter are the locks on your doors and windows, and your own competence. When that property is online, a laptop anywhere in the world can steal your stuff.

Despite such dangers, the cloud cannot and should not be stopped. We have much to gain from the freedom it offers. We want to be able to access "our" content or creations from anywhere—even if the possessions we access that way are not really ours after all. We want the peace of mind that comes from knowing that if our house burns down or is robbed, many of the real things that matter won't be lost.

Yet not all the limits physical reality places on possessions are unfortunate. Many are pro-consumer and pro-freedom. Alas, those have been conveniently left behind by the largely unregulated market in which cloud providers operate. If we want the best of both cloud and physical possessions, we must find some way to rebalance the scales and reassert our rights.

Laws that force cloud providers to be humane landlords to those renting space on their servers, much as most U.S. states regulate landlords of physical space, would be a good place to start. Physical landlords can't have a tenant's possessions trucked off to the dump without due process; even those who withhold rent are given a chance to fight eviction in court. Cloud providers should similarly be prohibited from deleting your data at will, and there should be a legally mandated process for moving digital possessions to another cloud—or copying it to your home computer. Likewise, we need laws that force cloud providers to respect the privacy of their customers.

The industry currently has no incentive to allow us to negotiate our terms of service. When the laws of physics can no longer protect consumers and citizens as they have in the age of physical property, it is the obligation of society to intervene with the laws of man. tr

SIMSON L. GARFINKEL IS AN AUTHOR AND RESEARCHER IN ARLINGTON, VIRGINIA, WHO FOCUSES ON SUCH TOPICS AS COMPUTER FORENSICS AND PRIVACY.

hack

Pushing the Limits of the Touch Screen

An engineer has rigged up several devices that enable a touch interface to respond to nuances such as pressure.

By ERICA NAONE

MAKING pinching or flicking motions against the screen of a smart phone or tablet is often more intuitive than navigating a computer screen with a mouse, but Michael Knuepfel thinks touch screens can do much more. Knuepfel, who just graduated from New York University's Interactive Telecommunications Program, has created devices that enable the screens to register more aspects of a user's touches. His goal is to make touch-screen interactions "more tactile, more physical, and potentially more expressive and fun."

B VIDEO-GAME CONTROLLER

Playing most video games involves pressing buttons quickly, acting by feel rather than sight. A touch screen is difficult to use that way, so Knuepfel turned one into a game controller by adding physical buttons. He applied conductive material that creates an electrical path from a finger to the screen when a button is pressed.

A TOUCH SCREEN

Knuepfel's devices work with "capacitive" touch screens such as the one in this iPad. The iPhone, as well as most smart phones and tablets, uses similar technology. It works by detecting the way a user's finger disrupts the pattern of electrical charge on the screen. Like the moves and clicks of a mouse, this information can be converted into an input.

C PULSE GENERATOR

Knuepfel modified an electrode with external circuitry and duct-taped it to the screen to create a prototype pulse generator. The electrode simulates the human touch and sends touch "pulses" at a rate detected by the screen. Analog inputs, such as information about varying volume or pressure, could be converted into a faster or slower series of pulses so that the touch screen could process them.

www See Knuepfel's devices in more detail: **technologyreview.com/hack**

D LIGHT-SENSOR OUTPUT

To make his creations even more useful, Knuepfel wants them to be able to receive data from the touch screen in addition to providing it. For example, he created a prototype robot that has a light sensor and can sit on top of a touch screen. When a user touches the screen, the device translates the gestures into light patterns; the robot detects them and moves accordingly.

E MECHANICAL STYLUS

Today's touch screens respond the same way no matter how hard you press on them. Knuepfel's mechanical stylus demonstrates one way that could be changed. The device has two arms, which spread farther apart as the user applies more pressure. Software detects the distance between the arms, thinning or thickening a corresponding line that appears on the screen.

F SIGNET RING

Capacitive touch screens can also accept input from multiple simultaneous touches. That's the basis of a low-level security feature Knuepfel designed. He made rings that use conductive material to create several electrical pathways from the user's fingers to the screen. These pathways are arranged in a distinct pattern; software on a tablet could look for a user's pattern before allowing access to private content.

G SOUND STYLUS

This stylus includes a wire that plugs into an iPad's microphone input jack. Pressing the stylus to the screen generates pulses of sound that speed up with greater pressure. The software interprets the sound data to thicken or thin a line drawn by the stylus.

JOSHUA SCOTT

demo

1

PAUL McMULLIN

Printing Parts

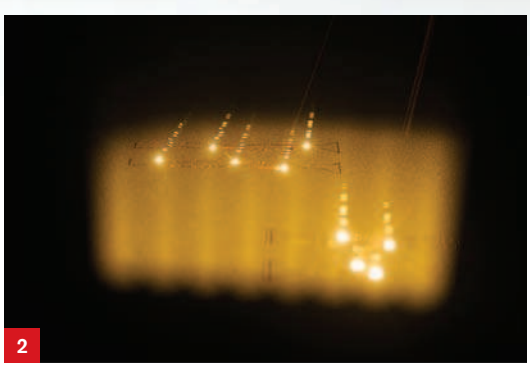
Systems that print mechanical components with metal powder could be used to build lighter, more efficient airplanes.

By STUART NATHAN

Chris Turner, an engineer at EADS Innovation Works near Bristol, England, twists a lever on a boxy black machine, and a porthole opens to reveal a dark cavity with a floor covered in gray powder. An invisible beam sweeps across the powder, and sparks fly. The box is an additive-layer manufacturing machine, sometimes known as a 3-D printer, and it is making a small part for an Airbus A380 airliner. EADS, which owns Airbus, hopes the device can transform manufacturing. Among other things, it could produce parts that make airplanes lighter, so they use less fuel.

3-D printers can make complex shapes that can't be manufactured with conventional techniques. Until recently, however, they couldn't print strong, durable objects. The machine Turner is using can make intricate forms out of high-grade metal, an advance that has allowed researchers to apply the design possibilities of 3-D printing to mechanical parts. The printers use software that works out where the parts need to bear loads and places material just in those areas, halving the weight of the complete part without sacrificing strength. That saves energy, metal, and money. The complex, curving forms that result couldn't be cast in a mold or carved out of a larger block even with the most advanced computer-controlled tools, but they can be printed in a succession of layers tens of micrometers thick.

Turner is testing whether printed parts can stand up to use in airliners, helicopters, and spacecraft. "Once we know that, we can scale up," he says. "We could adapt this to make large aircraft components." The possibilities include wing spars, the long beams that support wings.



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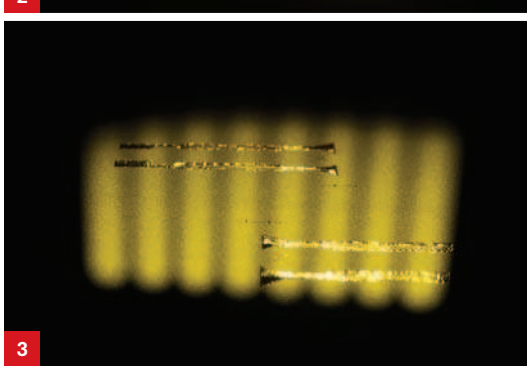

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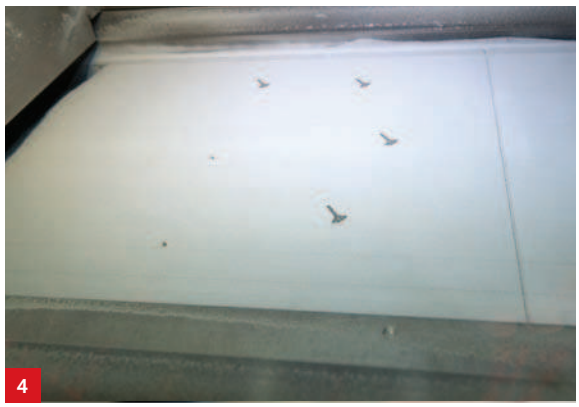
Before and after: Two versions of a hinge for a jet-engine cover illustrate the capabilities of 3-D printing. The one in the background is made with conventional manufacturing methods. The printed shape in the foreground weighs half as much.

1. After entering data from design software into this 3-D printer, engineer Chris Turner watches as it forms the hinge layer by layer. A layer of fine metal particles is spread on the printing surface, and the machine uses a beam of electrons to fuse them into solid shapes in the designated areas.

2. The electron beam sketches the outline of a cross-section of the part onto a thin layer of a powdered titanium alloy.

3. The beam completes its sweep, filling in the outline to form one layer of the part. The table supporting the fused metal then descends by 70 micrometers, and another layer of metal powder is spread on top. This process repeats until the entire part has been built.



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4. When printing is complete, finished parts are embedded within a block of powdered metal. Only the tops of the parts are visible.

5. An engineer removes the leftover powder from around the printed parts. The machine shown here is a second type of 3-D printer that fuses the powder using lasers rather than electron beams.

6. Components begin to emerge from the block. Because the leftover powder can be reused to build more parts, the technique results in up to 95 percent less waste than machining processes.

7. The finished components correspond exactly to an original computer model. The parts on the left are shaped like a conventional component. The ones on the right are the same component optimized to reduce weight. The size of the parts that can be made is currently limited by the size of the cavity inside the 3-D printer. Scaling up the process to print large parts could involve a printing head mounted on a crane that would deposit powder and melt it at the same time, using a laser or an electron beam.

www See the 3-D printer in action: **technologyreview.com/demo**

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from the labs

MATERIALS

Practical Invisibility Cloaks

Printing technique yields large sheets of light-bending materials

SOURCE: "LARGE-AREA FLEXIBLE 3D OPTICAL NEGATIVE INDEX METAMATERIAL FORMED BY NANOTRANSFER PRINTING"
John Rogers et al.
Nature Nanotechnology 6(7): 402–407

RESULTS: Researchers have developed a stamp-based printing method for generating large sheets of metamaterials, a new class of materials that interact with light in ways not seen in nature. They've used it to make sheets of a metamaterial that measure nearly nine centimeters per side, orders of magnitude larger than was previously possible. Tests showed that this material, which bends light backward, actually has better optical properties than materials made using more complex methods.

WHY IT MATTERS: Small-scale experiments suggest that metamaterials might be used to make invisibility cloaks, superhigh-resolution microscopes, and other exotic optical devices. But so far researchers have been unable to create such devices at a practical scale because metamaterials are difficult and time-consuming to make. Slow, precise methods such as electron-beam lithography have typically been used to carve intricate nanoscale patterns into the layers of metals and other components that make up these materials. The largest pieces previously produced were only a couple of hundred micrometers long.

METHODS: The researchers started with the design for a metamaterial that others had produced a few years ago, using slower methods. They made a hard plastic stamp patterned with the grid stipulated by the design. Then they "inked" the stamp in an evaporation chamber by depositing several thin films: first a sacrificial layer, then layers of the metal and dielectric materials that make up the metamaterial. Finally, they set the stamp on a surface and chemically treated it to dissolve away the sacrificial layer, freeing the metamaterial from the stamp. The stamp was pulled away, leaving the metamaterial on the surface. Each stamp is reusable and inexpensive to make.

NEXT STEPS: The researchers expect that by using more than one stamp, they will be able to make much larger metamaterial sheets. The method can also be adapted to work with other metamaterial designs, but the researchers hope other scientists will use it to make large amounts of this particular material for cloaking and other applications.

A METAMATERIAL DISGUISE
Big swatches of cloaking material can be printed with a stamp.

J. ROGERS, UNIVERSITY OF ILLINOIS

Transparent Batteries

Electrodes with features smaller than the eye can resolve could lead to see-through electrical devices

SOURCE: "TRANSPARENT LITHIUM-ION BATTERIES"
Yi Cui et al.
Proceedings of the National Academies of Sciences, published online July 25, 2011

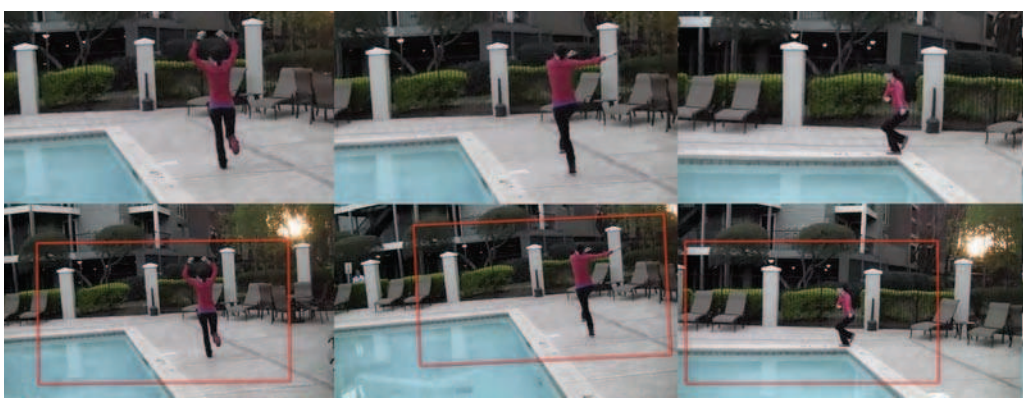
RESULTS: Researchers have made fully transparent batteries and used them to power a light-emitting diode. The prototypes can store as much energy as a nickel-

cadmium battery of the same volume.

WHY IT MATTERS: Transparent batteries are the last missing component needed to make transparent displays and other see-through electronic devices. Researchers have previously made transparent variations on other major classes of electronics, including transistors and the components used to control displays.

METHODS: The researchers designed electrodes made from a mesh in which all the lines are on the order of 50 micrometers—smaller than is visible to the human eye, so the result appears transparent. To make the electrodes, they first used lithography to carve a silicon wafer into a mold with a raised grid pattern. Liquid PDMS, a clear, squishy polymer, was poured over the mold and peeled away once it solidified. Researchers then dropped a solution containing standard materials for lithium-ion electrodes onto the grid of narrow channels on the surface of the PDMS sheet. Capillary action pulled the materials into the sheet until all the channels were filled, creating the mesh. Finally, the researchers sandwiched a clear gel electrolyte between two electrodes and encased the entire system in a protective plastic wrapping.

NEXT STEPS: The researchers want to improve energy storage by an order of magnitude—to about 200 watt-hours per liter—by reducing the thickness of the polymer substrate and deepening the trenches that hold the electrode materials.



STEADY HAND New software from Google focuses on key elements of a video to stabilize footage.

MATTHIAS GRUNDMANN

INFORMATION TECHNOLOGY

Stabilizing Video

A new system cleans up shaky amateur footage

SOURCE: "AUTO-DIRECTED VIDEO STABILIZATION WITH ROBUST L1 OPTIMAL CAMERA PATHS"
Matthias Grundmann et al.
Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, Colorado Springs, Colorado, June 21–23, 2011

RESULTS: Google researchers have developed a technique that removes the effects of an unsteady filming hand on amateur video. After showing that they were able to smooth out footage in real time while maintaining focus on key elements in the image, they used their algorithm as the basis for a stabilizer application that runs in real time at www.youtube.com/editor.

YouTube, the largest site used for sharing amateur video, did not previously have a stabilizing feature in its nine-month-old Web-based video editor.

WHY IT MATTERS: Shaky footage has always been a mark of amateur filmmaking, since amateurs usually lack the costly equipment that professionals use to stabilize their cameras. Some algorithms are available to clean up this effect, but those typically remove jerking effects without correcting others, such as the slow bounce of a camera held by a person walking.

METHODS: The algorithm begins by identifying key objects in the image and using them to plot the path traveled by the camera. It then determines a "best path," which represents the smoothest course for the camera to have traveled. By cropping the frames, it is able to adjust the footage so that the camera appears to have traveled the best path. The algorithm uses tools such as face detection to make sure it doesn't remove key components of the video in the process. Because the computational work is distributed among many machines, the system is fast enough for editing in a browser in real time.

NEXT STEPS: Right now, the user has to specify what size the system should crop the frames to; the algorithms find the optimal path for the given size. In the future, the researchers plan to adjust the system so that it can calculate the ideal size on its own.

Faster Memory

Prototype phase-change memory drive is faster than conventional disks

SOURCE: "ONYX: A PROTOTYPE PHASE-CHANGE MEMORY STORAGE ARRAY"
Steven Swanson et al.
USENIX Workshop on Hot Topics in Storage and File Systems, Portland, Oregon, June 14, 2011

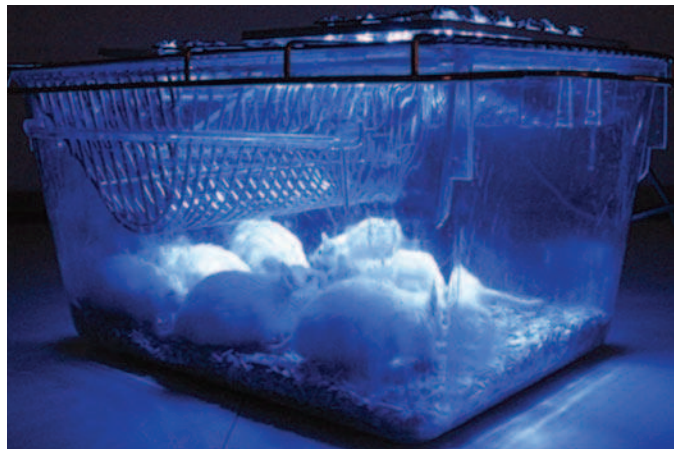
RESULTS: A prototype disk drive built using phase-change memory chips, which store data in the crystal structure of a metal alloy, proved capable of both reading and writing some types of data faster than a commercial conventional

flash drive. It was between 70 and 120 percent faster at writing chunks of data the size of a short text-only e-mail.

WHY IT MATTERS: Phase-change memory has the potential to overcome a limitation that has constrained computer design for decades: data can't be written to or read from disk storage nearly as fast as a processor can work on it. This new type of memory has only recently been incorporated into prototype chips; using them to build a working disk drive demonstrates how this technology might help improve computers and clarifies the remaining barriers to commercialization.

METHODS: Researchers at the University of California, San Diego, built the prototype using phase-change chips made by Micron, a company working to commercialize the technology. The chips record digital *1*s and *0*s by using small bursts of heat to flip the arrangement of atoms in an alloy made from elements called halcogenides between an ordered lattice and an amorphous phase. The researchers built those chips into circuit boards that usually hold conventional memory chips. They also added circuits to translate between the computer's requests and the stored data.

NEXT STEPS: The researchers are using their prototype drive to understand how significantly speedier data storage could lead to more powerful computer designs.



DIABETIC BLUES Cells implanted in these mice have been genetically engineered to trigger insulin production when exposed to blue light.

BIOMEDICINE

Light Control

Scientists use light to direct gene expression in mice

SOURCE: "A SYNTHETIC OPTOGENETIC TRANSCRIPTION DEVICE ENHANCES BLOOD-GLUCOSE HOMEOSTASIS IN MICE"
Martin Fussenegger et al.
Science 332(6037): 1565–1568

RESULTS: Researchers have developed a way to control gene expression with light. In cultured cells, the timing and intensity of light controlled both how much protein the target gene produced and when the production took place. When light-controlled cells were implanted in diabetic mice, researchers were able to manipulate the animals' insulin levels.

WHY IT MATTERS: Scientists now use chemicals to turn genes on and off, but light can be targeted more precisely. The technology could be used in research to study the role of different genes in development or other biological processes. By enabling precise control over protein production, it could also improve the manufacturing of drugs, such as some cancer therapies, that are made through biological processes rather than chemical synthesis. In the long term, cells engineered to carry the light-sensitive switch could be implanted into patients to produce a missing hormone, such as insulin, on demand.

METHODS: Researchers engineered cells to carry the gene for melanopsin, a light-sensitive protein from the human retina, which causes a surge of calcium inside the cell when exposed to light. That calcium surge activates a protein that can be linked to any gene a researcher wants to manipulate. Shining light on the cells to trigger the calcium thus turns on the target gene.

NEXT STEPS: The researchers plan to use the light-controlled system to produce protein-based drugs that have been difficult to make using traditional methods. They are also developing a light source that can be used inside a bioreactor, where the cells that produce proteins are grown.

Genome Editing

A new technique inserts genes at the right spot

SOURCE: "IN VIVO GENOME EDITING RESTORES HAEMOSTASIS IN A MOUSE MODEL OF HAEMOPHILIA"
Michael Holmes, Katherine High, et al.
Nature 475: 217–221

RESULTS: Researchers used a precise method of "editing" the genome to treat mice with hemophilia, replacing a defective gene with one that promotes blood clotting. After the treatment, the mice produced enough of the protein to speed clotting time.

WHY IT MATTERS: Researchers hope the technology will help overcome a major problem with existing forms of gene therapy, which introduce a new gene at a random point in the genome. That can disrupt other genes, in some cases causing leukemia.

METHODS: The technology relies on proteins known as zinc fingers, which bind to specific pieces of DNA to regulate nearby genes. By engineering different zinc fingers and attaching them to a gene-cutting enzyme, researchers have created tools that can snip the genome at a specific place and repair the target gene.

NEXT STEPS: The technology will next be used in dogs, which are often used to test hemophilia treatments. Before the treatment can be tested in people, researchers need to make sure it is does not snip DNA in unintended locations. tr

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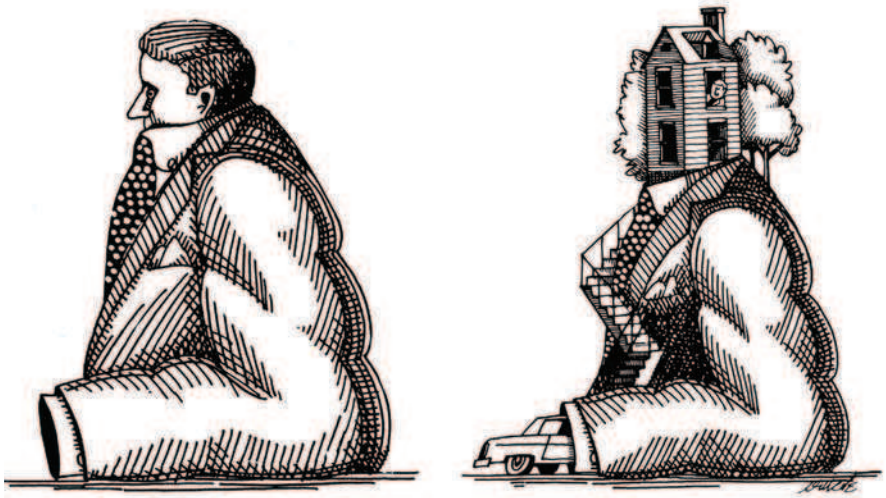

LET'S GET SMALL There would be all kinds of perks to being smaller, said a 1967 *TR* article. For one, it would be easier to find parking.

The Shrinkage Solution

Wherein a pair of MIT civil engineers proposed a novel way to lessen our environmental impact.

By TIMOTHY MAHER

In 1966, a Nobel Prize–winning biologist named Joshua Lederberg suggested, in an essay in the *Bulletin of the Atomic Scientists*, that because human evolution could now be directed by scientific means, we ought to seriously consider what kinds of changes we might like to see. A year later, in a provocative—and bizarre—essay for the July 1967 issue of *Technology Review*, a pair of MIT civil-engineering professors named Robert Hansen and Myle Holley considered one such change: making people smaller.

We wish here to comment on one kind of human change—a change of physical size—which apparently would be far less difficult to achieve than the modifications we infer to be potentially feasible through genetic alchemy. Indeed, it is our understanding that controlled, substantial modification of size may require only the judicious application of findings in the area of endocrinology.

The authors never got into the specifics of *how* humans might be made smaller, or how much smaller they should be. They acknowledged that the idea would probably generate "widespread antagonism," but they argued that given our emerging capacity for genetic engineering, it would be reckless to ignore the possibilities altogether: "Can we afford *not* to consider, in all its aspects, the question of human size?"

If, as the authors believe, the question of human size merits thought, it appears more reasonable to consider a decrease rather than an increase in size. First, an increase in size would clearly aggravate the problems we already associate with our excessive rate of population growth. Second, the advantages of large size and physical strength (in the performance of useful labor, the resolution of individual and group conflicts, etc.) have been almost entirely eliminated by technology.

Smaller people, they wrote, would need less food and tinier houses. They'd create less waste. And the smaller you are, the bigger the world seems. "A reduction in man's size might be compared to an increase in the size of the earth," the authors noted.

Consider, as but one example, the relation of man's size to the facilities provided for his transportation. Smaller man could mean smaller vehicles, either smaller highway rights of way or greater capacity for existing highways, easier provision for off-street parking ... Similar benefits of smaller human size become apparent in buildings.

In a section called "What Price Man's Shrinkage?" they addressed the "problems of transition." For instance: How would people react emotionally to such a proposal? Would they be less able to endure cold weather? And at what rate should the shrinkage occur? Five percent per decade? Twenty-five percent?

Allowing for an inevitable transition period, will smaller man really be comfortable in lesser space (or volume) than his larger predecessors have come to expect? ... If a change in size appears desirable, what incentives, if any, will lead to its achievement through free, individual choice?

Strange as the argument sounds, it did resonate as late as 1995, when an essay in *The Futurist* briefly cited Hansen and Holley's work in *TR* before pointing out that pygmies are physically fine at four and a half feet tall. Hansen and Holley emphasized that they weren't necessarily advocating making people smaller—they were simply (as Lederberg advised) giving the idea the careful thought they believed it deserved.

Needless to say effective consideration of this question will require not only effort within the scientific and humanistic communities, but frank and sympathetic interactions between the two. The end product of such inquiry and debate is not predictable. Possible conclusions range from feasibility, desirability, and moral acceptability to impossibility for technical, social, or other reasons. But need we prejudge the issue? Or should we seriously study the question? tr

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